KONINKLIJKE AKADEMIE VAN WETENSCHAPPEN
TE AMSTERDAM

PROCEEDINGS

VOLUME XXIX

N°. 2

President: Prof. F. A. F. C. WENT
Secretary: Prof. L. BOLK

(Translated from: "Verslag van de gewone vergaderingen der Afdeeling Natuurkunde", Vol. XXXIV and XXXV)

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Botany. — *"On the occurrence of striped and totally red coloured inflorescences on the same plant with Dahlia "Helvetia".* By F. J. M. OFFERIJNS. (Communicated by Prof. F. A. F. C. WENT.)

(Communicated at the meeting of November 28, 1925).

For some years past I have cultivated the single Dahlia variabilis Desf. "Helvetia", which garden-flower shows the peculiar phenomenon that besides the normal red and white striped flowers, plain red flowers may also suddenly occur. This is considered as an example of bud-variation. One characteristic of this occurrence is the unexpected appearance of this varying form and the marked difference between variation and normal form. Little is known as yet with certainty about the coming into existence of bud-variations in general. In order to be able to give an explanation of this phenomenon the development of the plants must be carefully watched : *a.* with continued asexual reproduction, — *b.* with sexual reproduction (after self-pollination) of the normal part, — *c.* with sexual reproduction (after self-pollination) of the varying part.

In this provisional communication (the investigation is being continued) only phenomena observed on plants of asexual reproduction are discussed ; yet I am of opinion that these observations may already to some extent shed a different light on Dahlia "Helvetia".

Where bud-variation is dealt with, it is, as a rule, implicitly assumed that the normal and the varying forms are distinctly or fairly distinctly differentiated. In the case of Dahlia "Helvetia" it appeared to me that this assumption is wrong.

A great series of widely divergent forms associated as it were with each other, through intermediate forms, may easily be found here.

Continual observation since 1923 induced me to establish the following facts : All the plants taken into cultivation developed besides the normally striped inflorescences also the plain red bud-variation. One plant developed the latter in an exceptionally small number (only three during the whole flowering-season of 1925, namely in the latter part of that time). The red colour is caused by the presence of anthocyanin in the vacuole-sap of the cells of the papillate epidermis.

The impression of well-defined forms is particularly produced by the fairly often occurring fact that normal form and bud-variation develop side by side. This impression is strengthened by the red inflorescences which, with plants in their entirety, are at once conspicuous owing to colour and size, while the less conspicuous differences among the striped inflorescences are easily overlooked on superficial observation.

The cultivated plants displayed the phenomenon every successive year, the parts caused by the severing of the plants show the same characteristics. (Hence retention of the peculiarity within the clones.)

Fig. 1.

As a rule the red inflorescences are developed in greater numbers according to the progress of the flowering-season. This has also been stated by CRAMER [1]), who speaking of Dahlias says:

„Im Spätherbst erschienen mehrere gleichmässig rote Blüten auf den Pflanzen". He then continues: „Der farbige Saum dieser Dahlia-varietäten ist nicht scharf begrenzt, sondern geht allmählich in dem weissen Teil über. Alle diese Tatsachen machen es meiner Meinung nach wahrscheinlich, dass besonders die äusseren Bedingungen hier die Farbeunterschiede hervorrufen".

This is certainly different with Dahlia "Helvetia"; with this variety the red border compared with the white part is, as a rule, well defined. And what is more remarkable, in the white part the red colour develops in a totally different way. It would appear to me that the stripes and the

1) CRAMER, P. J. S.: „Kritische Uebersicht der bekannten Fälle von Knospenvariation". (Natuurk. Verh. Holl. Mij. van Wetenschappen, III, VI, 3, 1907).

turning red all over of the white part must be clearly distinguished, and that they are isolated phenomena. Although, in my opinion, one may not consider it a rule that the red flowers are developed in greater numbers later on in the flowering-season, as this individually diverges too much, I am inclined to think of the influence of external circumstances in the formation of red inflorescences.

The following is also in favour of my statement:

a. A plant, a shoot of which was partly gnawed through at the foot and which was consequently broken, had exclusively developed red inflorescences above the wound; just below the wound there was an uninjured stem on which only striped inflorescences were found.

b. The red inflorescences are always much larger than the striped ones (with many other plants excessive formation of anthocyanin is often attended with, for instance, an expansion of the leafsurface).

As has already been pointed out the so-called flowers are, properly speaking, inflorescences and for comparison with similar phenomena on other plants it is therefore desirable to regard the parts, in particular the ligulate flowers, separately. From this it appears that one may find not only striped and plain red ones, but also a large range of others; even entirely white ones are developed which may be gradually associated with the entirely red ones through all kinds of intermediate forms.

One may distinguish in the ligulate flowers three strips, the two outer ones of which with the distinctly striped forms are coloured red and, as a rule, clearly distinguished from the white centre strip.

The width of the red strips may vary, from very narrow to a certain

Fig. 2a.

maximum. This maximum is the width with the normal striped form; a further expansion in the width along the whole length at the cost of the white centre strip evidently does not take place. In the white centre strip the red expands from the foot upwards; this expansion is not always the same. Consequently it is possible to form a series commencing with a normally striped ligulate flower, and ending with a totally red one associated through intermediate forms (fig. 2*a* and *b*). The differences may be very minute, so that it is not difficult to increase the number of intermediate forms in such a series.

On comparing various ligulate flowers in the same stage of development,

Fig. 2*b*.

it appears that the white ones are always smaller than the striped ones and again the latter smaller than the red ones (fig. 3 and fig. 1). The white ligulate flowers make a weaker impression; as a rule they look somewhat shrivelled, soon get brown at the sides, and quickly fade (e.g. when transported). Even when in the same inflorescences white, red and striped ligulate flowers are developed side by side, the differences in size mentioned are obvious.

From this it also appears that the inflorescences do not always contain the same ligulate flowers, but that they may belong to various kinds (fig. 4). Evidently all combinations are possible; once I selected a score of different inflorescences and constructed them into a series, from a totally white inflorescence to a totally red one. The number of intermediate forms might in this case also be easily increased as there are no marked distinctions.

Yet, among all these combinations, two forms seem to occur more often, viz. the inflorescences with exclusively normally striped ligulate flowers and those with plain red ligulate flowers only. Inflorescences with white ligulate flowers only are rarely developed; they are always small and look shrivelled and poor. Fresh looking white forms are also met with, but rarely (fig. 3).

Fig. 3.

In conclusion another phenomenon may be mentioned. The normal forms have 8 ligulate flowers in their inflorescences; this also applies to the red inflorescences found on it. But besides this, plants are met with on which inflorescences are developed with 13 ligulate flowers, instead of the number mentioned. In this case the ligulate flowers are curled back lengthwise and folded upwards. Often these plants also bear heads which are excessively developed in width, an which produce the impression of having arisen through the growing together of two heads.

One plant bore three kinds of inflorescences at the same time, viz.

a. normally striped ones with 8 ligulate flowers, b. plain red ones with 8 ligulate flowers, c. striped ones with 13 ligulate flowers. How little distinct all the forms mentioned really are is also evident from the fact that inflorescences may be found in which both the flat ligulate flower of the normal kind and the folded curled one of the form with 13 ligulate flowers occur.

On comparing the tubular flowers from various inflorescences it appears that also the colour of the corolla petals and the anthers differs (yellow or more orange colour). It would appear to me that this case will not

really fall under the notion of bud-variation according to DARWIN and CRAMER, who emphasize the sudden, saltative appearance of the variation.

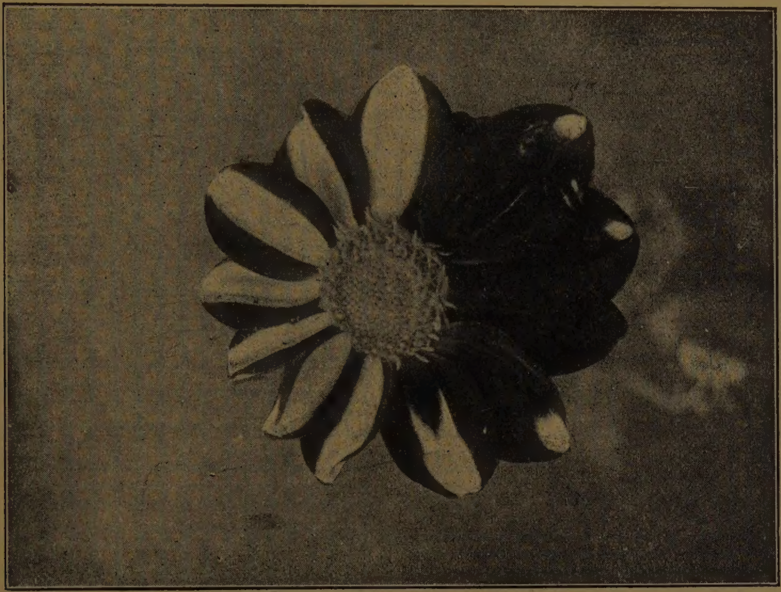

Fig. 4.

This indeed, is only seemingly the case with Dahlia "Helvetia". Whether the external circumstances exercise influence on the development of the various kinds of flowers, and to what extent, I hope to be able to investigate more fully.

Physiology. — *"On the presence of ganglion-cells in the circular muscle of the intestine of the cat. (prelim. commun.)"* (From the Laboratory of Histology and Embryology of the University of Utrecht. Dir. Prof. J. BOEKE.) By L. W. VAN ESVELD. (Communicated by Prof. J. BOEKE.)

(Communicated at the meeting of November 28, 1925).

When RANSOM in a summarising article on "afferent paths for visceral reflexes", discussing the influence of the plexuses of AUERBACH and MEISSNER on the movements of the intestinal wall, complains, — "that since next to nothing is known about the structure of these plexuses and the interrelations of the nervous elements which compose them, the problems relating to the control of the movements of the alimentary tract are very baffling" — then this saying is quite sufficient to show us how little we know about this theme and how necessary it is, that in this case as in others, histological and physiological investigations go hand in hand.

One of the questions which arise when we investigate the movements of the wall of the small intestine in a surviving state, as it was done for the first time by MAGNUS, and afterwards by GUNN and UNDERHILL, ALVAREZ and LUCILLE MAHONEY, is, whether ganglion-cells are present or not inside the circular layer of muscle-cells of the intestine of the cat, outside the plexus of AUERBACH and MEISSNER.

To show the good right of this question, it is necessary to describe here in a general way, including one or two details, the manner in which the investigators mentioned above made the preparations necessary for their experiments and to point out the entirely different conclusions, they drew from their experiments.

When we cut out a part of the intestinal wall of the cat, it is quite easy to remove the mucosa and submucosa, and it is even not very difficult to separate the circular and longitudinal layer from each other.

Together with the mucosa and submucosa we remove the plexus of MEISSNER, and when we separate the two layers of muscular tissue, the plexus of AUERBACH adheres practically entirely to the longitudinal layer. Only a few very much damaged portions of this plexus may be met with here and there on the outer surface of the circular layer, and it is possible to remove even this poor rests entirely, when we scratch (as it was done by MAGNUS) the outer surface of this layer with a crystal of nitras argenti, or when we follow the method of GUNN and UNDERHILL and take away, not only the longitudinal layer, but also the external layer of muscular cells. Only the inner portion of the circular layer is then used for the experiments.

In this way it is therefore possible to make a preparation of the muscular layer with or without the plexus of AUERBACH, and to investigate whether or not these preparations differ in their behaviour in a suitable milieu.

MAGNUS saw spontaneous rhythmical contractions in a preparation of the longitudinal muscle, which contained the plexus of AUERBACH, but found them absent in a preparation of the circular coat without any elements of the plexus. From this observations he drew the conclusion, that the automatic movements of the intestinal muscle are caused by nervous centra, lying in the plexus of AUERBACH and that therefore we have to consider these movements as of neurogenic origin.

GUNN and UNDERHILL who repeated the work of MAGNUS in the year 1914, succeeded in getting spontaneous rhythmical movements even in a small piece of the muscular coat, deprived of its ganglionic plexus. From this observation they concluded, that the rhythmical movements are of myogenic origin, and the same conclusion was drawn by ALVAREZ and LUCILLE MAHONEY in 1921.

When we ascribe the better results of the experiments of later years to the more delicate and refined technique of the recent experiments, even then the question arises, whether the conclusions drawn by GUNN and UNDERHILL c.s. from their experiments are entirely legitimate.

The investigators themselves felt, that these conclusions are open to severe criticism, where they built them upon the truth of the generally acknowledged anatomical statement — "namely, that AUERBACH's plexus is confined to the region between the circular and longitudinal muscle, and that the nerve-cells do not penetrate deeply into the circular muscle."

For it is true, that investigation of this matter shows, that this hypothesis is on the whole defendable and that only a few cells of the plexus of AUERBACH penetrate into the circular muscular layer, and even then only very superficially, but another hypothesis, which forms the basis for all the later investigations, viz. that these are the only ganglion-cells inside the circular layer, may be proved to be wrong.

This communication gives the preliminary results of an investigation of the possibility whether other ganglion-cells may be present inside the circular layer, and when that proved to be true, to see where these cells are to be found, and how they are distributed.

In literature we do not find much about this. PAUL SCHULTZ gives in his article some pictures of ganglion-cells inside the circular coat of the stomach of the frog and the dog, and R. MüLLER also draws the attention to the presence of cells of this character in the stomach of the frog, but that is all. An accurate description of these cells in the intestinal wall of the cat is not to be found.

The difficulties of such an investigation in this direction, especially when one tries to establish the entire number of ganglion-cells present, lies in the fact, that we do not possess a method of investigation of the

nervous system, which gives statistical results. By means of methylen blue or silver impregnation methods we are able to stain ganglion-cells with more or less reliable results, but by no means the entire number of cells present in a given preparation.

For a systematic investigation it, therefore, is necessary to use a non-specific staining method, which reveals in a certain way all the ganglion-cells present in the preparation. In this direction the iron-haematoxylin stain gives reliable results.

Small pieces of the intestinal wall of the cat were fixed in ZENKER's fluid to which was added before using it 5 % glacial acetic acid. These pieces were treated in the usual way after this fixation (B. ROMEIS, Taschenbuch der mikroskop. Technik, 11. Aufl. § 184.), inbedded in paraffine, cut into serial sections of 10 mu and stained with iron-haematoxyline and eosine.

In sections treated in this way all the ganglion-cells in the plexuses of AUERBACH and MEISSNER can be recognised with accuracy. They present themselves as large cells with a bluish red protoplasm and a large, round or oval clear nucleus, with one or two nucleoli and a distinct chromatic structure. These nuclei present such a characteristic appearance independent of the cells, that they alone are already sufficient to recognise the ganglion-cells even when the protoplasm of the cells is stained only faintly or not at all.

After having thus formed a definite criterium for the ganglion-cells I looked over my sections for them inside the circular layer, and soon I had the good luck to find them even there. The fact, that they are lying here surrounded by a tissue of an entirely different structure, causes them to be visible even under a low power, and nobody who examines the sections under the microscope or looks at the microphotoes, accompanying this communication, will fail to recognise these cells as true ganglion-cells when he compares them with the elements of the plexus of AUERBACH.

We find these ganglion-cells lying separately or condensed into more or less small groups (ganglia), lying at the side of the intestinal wall where the mesentery is attached to it or at the opposite side, we find them in the outer, middle or inner part of the circular layer, in short there is not a single part of the circular layer, however small, where it is not possible to find them, even when their number may be small and there are places of predilection.

That their number is small, may be shown in the following way:

When, in a given number of serial sections through the small intestine, we count the number of ganglion-cells present in the plexus of AUERBACH and MEISSNER, and when we take the average of these numbers, we may reckon after rather a rough method, in a section of 10 mu in the plexus of AUERBACH about 80 cells, in the plexus of MEISSNER about 150 cells.

In a series of 1000 sections of 10 mu through the wall of the small

intestine, I found in the circular muscle-layer no more than 165 ganglion-cells. So we find an enormous difference. In these 1000 sections were

Fig. 1. Circular musculature near the place of attachment of the mesentery. Above submucosa, below longitudinal muscle. Group of ganglion-cells lying in a strand of nerve-fibres, transversing the circular muscle-layer.

Fig. 2. Circular musculature opposite the attachment of the mesentery. Three ganglion-cells near the submucosa inside the circular layer.

present 80.000 cells of the plexus of AUERBACH, and only 165 inside the circular muscle-layer.

It was further of interest to investigate the mode of distribution of these 165 cells throughout the circular layer. For when experimenting with small pieces of this layer, most of the investigators remove that portion of the ring, which includes the place of attachment of the mesentery to the intestinal wall, partly because they suppose that the bloodvessels, which penetrate here in larger numbers into the intestinal wall than in other parts of the circumference, might take with them nerve-

strands including ganglion-cells, which might influence the movements of the muscular layer, partly because it is just at the place of attachment of

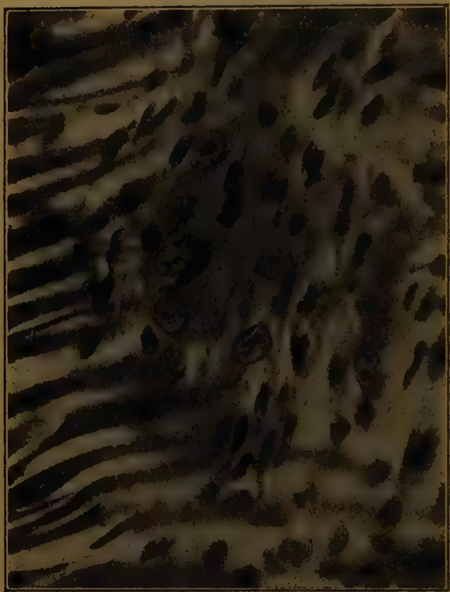

Fig. 3. Some of the ganglion-cells of Fig. 1, highly magnified.

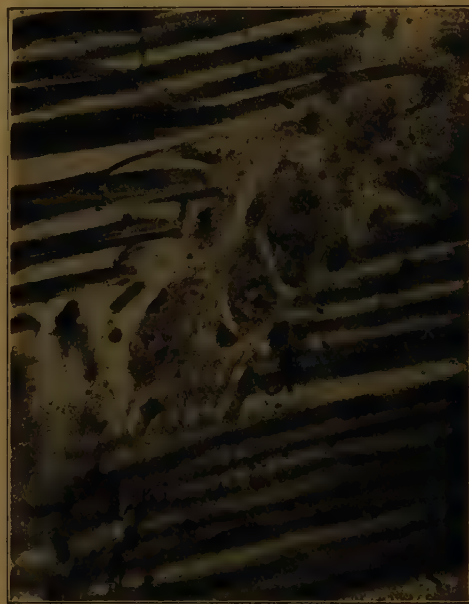

Fig. 4. The three ganglion-cells of Fig. 2, highly magnified.

the mesentery to the intestinal wall, that the different layers are difficult to sever, owing to the penetrating of the bloodvessels and the connective tissue accompanying them into the intestinal wall at this place of junction.

Of the 165 ganglion-cells found in my sections, 98 were lying in that portion of the circular layer, which corresponds with the line of attachment of the mesentery to the intestinal wall. The remaining 67 ganglion-cells were distributed throughout the other portion of the circular layer, which certainly was 4 or 5 times as large as the first piece. So the difference appeared to be very obvious.

Not only the number of ganglion-cells found in the neighbourhood of the mesentery appeared to be greater, but also the ganglion-cells were united into larger groups here than at the other side.

In the portion of the intestinal wall close to the place of attachment of the mesentery, I found groups of 8, 9, 25, in one case even of 41 ganglion-cells.

In the remaining portion of the muscle-layer, I found many separate cells and small groups of 3—5, never more than 6 cells. This is easely explained by the presence of the large nerve-strands, mentioned above, which penetrate into the circular layer from out the plexus of AUERBACH, and which appear to be connected with the plexus of MEISSNER, as far

as may be concluded from the sections stained after the method mentioned above.

Only when we succeed in staining the cell-processes of these cells by one of the impregnation-methods, we will be able to form a distinct opinion on the character of these cells, whether they belong to the first or second type of ganglion-cells described by DOGIEL, and what may be their (purely hypothetical) function.

Although this preliminary investigation is not on a sufficiently large scale to enable us to draw conclusions from large numbers, still I am of opinion that further investigation will not alter these conclusions very much, and that we may summarise our results in the following way:

1. though present only in small numbers, ganglion-cells may be found in every portion of the circular muscle of the intestinal wall of the cat.
2. the larger groups of ganglion-cells and the larger number of cells may be found in that part of the intestinal wall, where the mesentery is attached to the intestine.

From this the conclusion may be drawn, that it never shall be possible, whatever method is followed, and whatever part of the intestine is taken, to make a preparation of the circular-muscle-layer, of which we may say, that is does not contain ganglion-cells, without a previous histological examination. And in the second place it follows, that the chance to get a preparation without ganglion-cells, will be the greatest, when we remove that part of the muscle-ring, which lies near the place of attachment to the mesentery.

That it is possible indeed to get such a preparation, consisting only of muscle-cells without a single ganglion-cell of the type described, and still being of the size of the muscle-pieces generally used for the physiological and pharmacological experiments, I was able to prove in the following case. A preparation of the inner part of the circular muscle-layer was made by Prof. GASSER of London, used by him in an experiment, during which it showed regular rhythmical contractions, and then put in ZENKER's fluid and sent to Utrecht. Within 24 hours it was in my possession. It was then rinsed, dehydrated, imbedded in paraffine, and cut into 188 serial sections of 10 mu.

In these 188 sections not a single ganglion-cell was found. It was true, that the fixation was not so beautiful as was the case with entirely fresh specimens, but the absence of ganglion-cells could be stated with certainty.

Even if a few ganglion-cells had been found, such as may be present in such a small piece of muscular tissue, it would be highly improbable, that these would function as centra for the rhythmical contractions, but the entirely negative result of the histological examination of the tissue in this case supplies the positive proof, that rhythmical contractions may be procured without these ganglion-cells.

So it seems, that the adherents of the myogenic theory of the movement

of the intestine are in the right, and yet at the end of this communication I will draw the attention to a histological problem, which is intended to throw an entirely new light on this whole question, and that is the problem of the so-called "interstitial cells of CAJAL", held for nervous elements by several investigators (CAJAL, LA VILLA, ERIK MüLLER), for connective tissues by others (DOGIEL, M. HEIDENHAIN, CARL HUBER).

These interstitial cells are small fusiform or triangular cells with a number of cell-processes, often branching at right angles. They may be stained with methylene blue or silver, they are found in largest numbers inside the nervous plexus, but still they are very numerous inside the other layers of the intestinal wall, especially inside the muscular layers.

Dr. LAWRENTJEW, who has been investigating them in our laboratory, maintains [1] that they are of nervous origin. If this is really true, which it seems to be in my opinion, then in every piece of the musculature, however small it may be, there are present nervous elements in such numbers, that they must certainly be taken into account when the origin of the rhythmical contractions is under discussion, and so the solution of the problem of the myogenic or neurogenic origin of these contractions is put away as far as it was before.

So we see, that even in 1925 the problems relating to the control of the movements of the alimentary tract are still "very baffling". There is still a wide field lying open for histological and pharmacological investigations.

Utrecht, November 1925.

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Botany. — *"Concerning the difference in sensibility of the tip and base of Avena to light."* By F. W. WENT. (Communicated by Prof. F. A. F. C. WENT.)

(Communicated at the meeting of October 31, 1925).

The curvatures of plants under the influence of unilateral illumination are explained by the theory of BLAAUW (2) which states that they are caused by the lightgrowthresponse of the two opposite differently illuminated sides of the organ. This theory has frequently been discussed especially on ground of statements made about seedlings of Avena. But VAN DILLEWIJN (4) has lately described accurate experiments which prove that the positive and negative curvatures of these seedlings can wholly be explained in the sense of BLAAUW and so further foundation is given to this theory. The principal literature on the subject is cited by him.

In order to solve the problem definitely, we must get better information about the lightgrowthresponse. The following paper will deal with the analysis of this response. The experiments were carried out with the seedlings of a pure line of Avena sativa (Segre-oats). The responses were registered automatically by the auxanometer of KONINGSBERGER (6).

The first task I set myself was to carry out experiments on the following problem : Is there any difference between the lightgrowthresponse of the tip and the reaction of the lower part of the seedling appearing after illumination ? Theoretically one may expect the former response to be much stronger than the latter according to the supposed parallelism between curvature and lightgrowthresponse. For phototropic experiments show that the tip is far more sensitive to light than the base (ARISZ 1).

The way to get data on this point is to illuminate only a part of the plant. Up to now only SIERP has carried out some experiments with partial illumination. He found, though rather vaguely, that a lightgrowthresponse also appears after illumination of the base only (9).

I began with two series of experiments. At first I illuminated 2.5 mm of the tip of a coleoptile and recorded the resulting response ; in the second series the tip about 6 mm long was kept in the dark, whereas the base was illuminated. To illuminate only part of the coleoptile I placed a little black tube around the rest so that the 3 horizontal incident lightrays could reach only part of it. In this way the darkened part received only a very small quantity of indirect light, which can hardly have had any influence on the results.

When after some time the growth in absolute darkness had become constant I illuminated the plant from 3 sides with an intensity of 31 M.C.

(photometrically controlled). The results are shown in fig. 1 and 2. Each curve is the average of 3 reactions, which corresponded very well with one another.

However, the reaction appearing after illumination of the tip is not

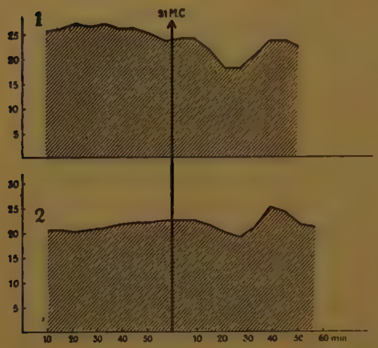

Fig. 1. Illumination of about 8 mm of the base, the top of 6 mm is kept in the dark. Average of three reactions.

Fig. 2. Only the top of 2,5 mm is illuminated Average of 3 reactions.

Lightgrowthresponses of the coleoptiles of Avena.
The ordinate represents μ growth per minute, the abscissa the time in minutes.
At ↑ the illumination from three sides with 31 M.C. began. Temp. 20° C., relative moisture 70 %.

stronger than that of the base; on the contrary the strongest reaction results after illuminating the base. Now a possible explanation of this contradiction is given by the following consideration. If we had illuminated the coleoptile unilaterally with the same quantity of light (> 3 × 50000 M.C.S.) it would have given rise to the so-called second positive curvature (ARISZ 1). It is a fact that this curvature likewise results after illumination of the base only. So it is to be understood that I had to use much smaller quantities of light, less than 4000 M.C.S. (when the negative curvature begins to appear). Thence I chose a 3-sided illumination during 5 seconds, with an intensity of 100 M.C.

These experiments were carried out at a constant temperature of 25° C., whereas all others were done at 20° C. The tubes for the partial illumination in these experiments were better than the former ones so that the indirect light falling on the darkened part was reduced as far as possible. The reactions with this small quantity of light hardly differ quantitatively and qualitatively from one another; so the average of 2 or 3 reactions gives a true representation of the ideal reaction. As the primary effect of light on the growth is its retardation and as the acceleration which follows seems to be an autonomical reaction of the seedling on this retardation (KONINGSBERGER 7) we can best characterize the lightgrowthresponse by determining the minima of the growth. By the total illumination of a coleoptile with 500 M.C.S., as shown in figure 3 as an average of 3 reactions, we find 2 distinct minima, one 17 min. and another 59 min. after illumination. After 2 hours the growth is rather constant again.

In figure 4 the same illumination is used but here only 1,25 mm of the

tip received the light. This reaction is very much like the preceding one, only the first minimum after 17 min. is missing and the growth gradually diminishes towards the minimum after 62 min.

Finally figure 5 shows us the reaction when only the base is illuminated

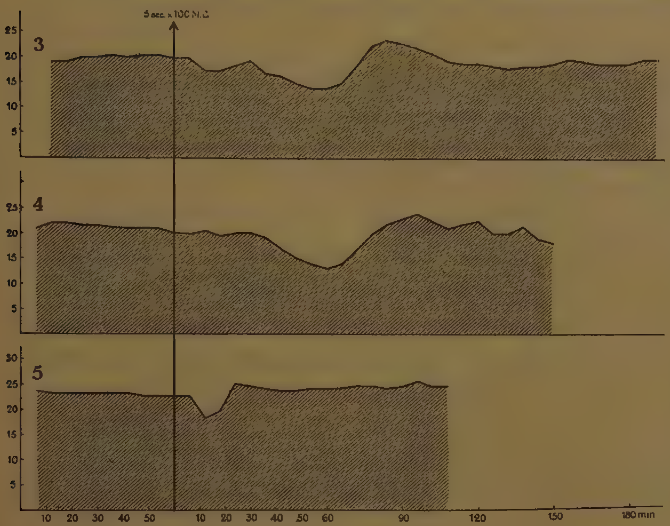

Fig. 3. Illumination of the whole coleoptile. Average length 12 mm above the earth, average of 3 reactions.

Fig. 4. Only the top of 1,25 mm is illuminated. Average length 11 mm above the earth; average of 2 reactions.

Fig. 5. Only 9 mm of the base is illuminated, the top of 3 mm is kept in the dark. Average length 14,5 mm above the earth; average of 2 reactions.

Ligthgrowthresponses of the coleoptiles of Avena.
The ordinate represents μ growth per minute, the abscissa the time in minutes.
At ↑ illumination from 3 sides with 5 sec. × 100 M.C. Temp. 25° C., relative moisture 80%.

and the tip of 3 mm is kept in the dark. Here after 15 min. appears only the first minimum and the second one is lacking.

It is apparent from the experiments mentioned above that the lightgrowthresponse of a coleoptile, illuminated with 500 M.C.S. is accomplished by the cooperation of *two reactions,* just as SIERP (9) already pointed out. So the first effect on a seedling will be a retardation of the growth owing to the illumination of the base, which leads to a minimum after about 16 min.; afterwards the velocity of growth increases, followed by a second slackening towards the minimum after about 60 min., which is due to the illumination of the tip. I shall call the lightgrowthresponse appearing after illumination of the tip only the *tipresponse* with a minimum of the growth after 60 min. (at least at a temperature of 25° C., at 20° C. it appears after 78 min.). The response resulting after illumination of all the lower parts of the seedling I call the *baseresponse.* Its minimum lies at 25° C. (20°) at 16 (24) min. but only if the time of illumination does not exceed a few minutes, otherwise the growth reaches its minimum somewhat later. The responses of KONINGSBERGER (6) with permanent illumination must be understood as baseresponses.

The existence of two different lightgrowthresponses is of great interest, especially for the explanation of the phototropic phenomena, as the following comparison will show.

As we know the first positive curvature appears only if the extreme tip of the coleoptile catches the light, and also if the quantity of light used does not exceed 4000 M.C.S. (these facts can be found in ARISZ (1)). The tipresponse possesses the same properties; here also it is only the tip which is able to react upon rather small quantities of light. By these facts we come to the following supposition in accordance with BLAAUW's theory: *the first positive curvature results from the different tipresponses of the proximal and the distal sides of the coleoptile.* Proof of this supposition is furnished by the figure of VAN DILLEWIJN (4) showing the responses after illumination with 10 sec. $\times$ 80 M.C. and 10 sec. $\times$ 2.5 M.C., which are both tipresponses. The second positive curvature appears after the administration of much more light, and here the whole coleoptile is sensible, for even if we darken the tip, the plant will show the curvature. The product rule of BLAAUW and FRÖSCHEL does not apply here, but it is the intensity of light that limits the curvature. If we compare these facts with those known about the baseresponse, we again find a striking resemblance, as KONINGSBERGER (7) proved that for his lightgrowthresponses (which were baseresponses) only the intensity of the light was of any importance. And in the same way the other figures of VAN DILLEWIJN (mentioned above) prove the probability of my view, that *the second positive curvature is the consequence of the baseresponses of the proximal and the distal sides of the coleoptile.* It must also be possible to explain the negative curvature by the cooperation of the tip and baseresponse.

On the surface of it, it seems very strange that the influence of light can cause two different responses at the same time in one organ. BLAAUW compared this double influence on the plant with the action of light on the photographic plate, where it causes a negative and, by solarisation, a positive.

But of course there can be no question about solarisation here, as the two responses appear at the same time. I think that the only way to explain these two different responses is by supposing the existence of two different ways of growth, both of which can be influenced, in a different way, by light. According to investigations especially of SÖDING (10) and NIELSEN (8), the probability of this supposition is very great. They found, that if the tip of a coleoptile was cut off, the remaining part continued its growth, but much slower. If the cut tip was replaced, the growth of the base increased very much. So we have to separate the *tipgrowth,* which is produced by substances stimulated in the tip and which shows its effect after their diffusion into the lower part from the (autonomic) *basegrowth* of the growing cells, which is also found in coleoptiles without a tip.

And thus I want to *explain the tipresponse by the action of light upon the tipgrowth,* whereas *the baseresponse is the result of the influence of light upon the basegrowth.* The cause of these considerations is that we must conclude that the tipresponse, as well as the first positive curvature and the

tipgrowth, is produced by diffusion. Now we understand why the tipresponse requires 60 or 78 min. to reach its minimum because the response is stimulated in the tip and then has to diffuse into the lower parts where it finally manifests itself. On the contrary, the baseresponse is stimulated on the spot, and is not bound to a limited percepting (induced) zone in the same way as the second positive curvature and the basegrowth, and accordingly it has reached its minimum much sooner than the tipresponse. Hence it follows that the longer the plant, the greater the baseresponse will be, because more cells will give a response.

The facts correspond very well with this conclusion. In the first place I classed the responses of two series of plants, illuminated with 500 and 800 M.C.S. according to their length. They all showed the same tipresponse, but those, of which the coleoptiles were 11 mm or shorter did not produce the baseresponse whereas the longer ones showed it very distinctly.

In the second place I could prove that the responses (baseresponses as mentioned before) recorded by KONINGSBERGER showed the influence of their length upon them very distinctly. In the following table I expressed the size of the response in the absolute retardation of the growth during the first hour after illumination. Only the responses upon very high intensities (400 M.C.) did not show these differences between the smaller and the greater plants.

Continuous 3-sided illumination with 25 M.C. (extracted from table I of KONINGSBERGER 7).

Length above the earth	Average length	Retardation of the growth
9—12 mm	10 mm	100 μ-minute
14—17 mm	15 mm	260 „
21—23 mm	22 mm	420 „

Thus the individual differences of the lightgrowthresponses can be explained partly by the varying length of the reacting plants.

Now I must come back to SIERP (9). He recognized the lightgrowthresponse as a complicated phenomenon, as he distinguished a primary and a secondary action of the light. But especially as regards his primary action I do not share his view, as he describes it as an undulation of the growth during an indefinite time. Now this primary action is practically the same as the baseresponse which is a very distinct response. I have seen a great amount of these baseresponses, and nearly all of them show only a retardation of the growth, followed by an acceleration. An hour after illumination the growth has regained its former speed, and is absolutely constant without any indication of undulations. Figure 6 shows the average

of 3 responses, carried out by the same coleoptile, the base of which I illuminated every 2 or 3 hours with 80 M.C. during 25 sec. The top of

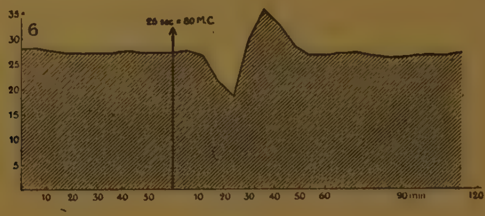

Fig. 6.

Lightgrowthresponses of the coleoptiles of Avena.

The ordinate represents μ growth per minute, the abscissa the time in minutes.

At ↑ the base is illuminated from three sides with 25 sec. $\times$ 80 M.C., the top of 3,5 mm was kept in the dark. Average length 24.5 mm above the earth; average of 3 reactions Temp. 20° C., relative moisture 70 %.

3.5 mm was kept in the dark. The 3 responses correspond nearly absolutely with one another, and so it is with my other responses. In this series of responses the quantity of light used did not exceed 10000 M.C.S.

Of course the case of Avena with its 2 kinds of growth is not a unique one, but all sorts of plants and organs will have their autonomic and induced growth. Thus the action of light, gravitation or chemical stimuli will in those cases give 2 different responses. I will not give an extensive survey of the literature with all the facts that could confirm this view, but I should like to mention some of them.

BLAAUW (3) recorded the lightgrowthresponses of the hypocotyles of *Helianthus*. His figures show us that the small quantities of light cause a response with a minimum after about 50 min. probably comparable with the tipresponse of Avena. If more light is used, a second minimum appears before the first one. The depth of this second minimum (to be compared with the baseresponse) increases as more light is used. So here the facts also point to the existence of two different responses.

A known fact is that the leafstalk of various leaves is able to curve when the surface of the leaf is illuminated as well as after illumination of the leafstalk itself, thus without the cooperation of the blade. Probably the autonomic growth of the leafstalk as well as the growth induced by the blade may be influenced by the light, both giving rise to a curvature.

As for the gravitation-stimuli there are facts also pointing to a double influence upon the plant. JOST and WISZMANN (5) published experiments with great centrifugal forces (> 1000 g) working on roots. They saw negative curvatures of roots also if the tip had perished. For the usual geotropic curvature the presence of the tip is necessary; in all probability the tipgrowth is influenced here, whereas in the case of JOST the basegrowth plays a part.

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Utrecht, October 1925. *Botanical Laboratory.*

Botany. — *"Latex as a constituent of the cell-sap."* By F. A. F. C. WENT.

(Communicated at the meeting of February 27, 1926).

The number of investigations on the latex of plants has greatly increased during the last years, mainly due to the extension of rubber-cultivation. Yet it cannot be said that latex has lost much of its obscurity. Even the locality of the latex in the interior of the cell is not yet known with sufficient accuracy. This is conceivable because latex is to be found in long tubes or vessels, which will always be opened when the preparation is made. This can be no objection in fixed preparations, but when carrying on an investigation on the living plant, it will be almost impossible to prevent the injury of the cell, so that no safe deductions can be drawn about the cell contents.

The investigations of MOLISCH [1]), however, have made it probable that the chief elements of the latex are derived from the cellsap, that the solid particles are situated in the interior of the vacuole. MOLISCH came to this conclusion after he found vacuoles in the slime extruding from cut up leaves of Musa, and partly also after he examined sections of stems of Euphorbia and other laticiferous plants in which cases, however, the latex-tubes were hurt. This last circumstance makes his results rather doubtful though it must be conceded that the representation of MOLISCH looks very probable. Also an investigation of the extruding latex gives rise to objections because it may change during the extrusion.

Now, a short time ago, W. BOBILIOFF [2]) could show that in intact laticiferous tubes which he succeeded in isolating and cultivating separately, small particles of the latex are indeed to be found in the cellsap. Yet, it is perhaps of some interest to mention here a few of my own observations which were made three years ago during a stay of a month at the Raleighfalls in the interior of Surinam. The objects of these investigations were several species of Podostemonaceae.

When great plants of Mourera fluviatilis are cut, a white milky juice comes forth which has the same appearance as any other latex ; with the smaller forms there can generally be no question of such an extrusion. Yet, similar substances may also be found there as I shall show in the next pages. The small particles of this sap are soluble in alcohol, so the

1) H. MOLISCH : Ueber Zellkerne besonderer Art. Botanische Zeitung. LVII. 1899, p. 177.
" : Studien über den Milchsaft und Schleimsaft der Pflanzen. Jena 1901.

2) W. BOBILIOFF. Waarnemingen van melksapvaten in levenden toestand. Archief voor de Rubbercultuur in Nederlandsch-Indië. Mededeelingen uit het physiologie-fonds 9. 1925, p. 313.

investigator, who works with alcoholmaterial in Europe does not see much of the presence of this latex.

Yet, several former investigators have already pointed out that secretory tubes are present. First of all GOEBEL [1]) who describes that in cutting the leaves of living plants of Rhyncholacis macrocarpa „ein gelbes Sekret in ziemlicher Menge ausfliesst". Afterwards WÄCHTER [2]) has given a description of secretory channels in Weddelina squamulosa and a few years later we find some short remarks on this subject made by MILBREAD [3]) on several species from different genera of this family. A detailed description has been given by MATTHIESSEN [4]). The only trouble is that no investigator, except GOEBEL, has observed the living plants. Therefore, it may have some sense when I mention what I have observed in the living plants. Of course I made some complementary investigations on material which after fixation I brought with me to Europe.

I already made the remark that with the larger forms the outflow of the latex may be easily seen after making an incision, but that this is not the case with the smaller species. Notwithstanding this, the secretory cells or channels are conspicuous enough even there, because they strongly reflect the light, so that they may easily be seen as bright white spots or streaks on a dark lining; even a microscope is not always necessary although it makes them more distinct.

I have already mentioned that the substance which reflects the light so strongly is soluble in alcohol. For this reason a search was made among the reagentia which I had taken along with me in order to know whether some of these would leave the secretory products untouched and yet might be used as a conserving fluid. It became evident that a strong solution of corrosive sublimate may be used as such and accordingly several of these plants were taken with me in this conserving fluid in order to investigate them more closely here in Utrecht.

This investigation made it clear that these secretory cells are present in almost every part of all the species of Podostemonaceae which were examined. This is best shown by the following list:

1. Mourera fluviatilis. In the so-called "gills" secretory cells are found which are not differentiated from other cells by their form. They are never found in the epidermis, but lie subepidermal. In other parts of the leaf these cells are generally somewhat stretched in the direction of the longer axis of the leaf, in the stem they become long laticiferous channels of which the description though was already given by MATTHIESSEN;

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1) K. GOEBEL. Pflanzenbiologische Schilderungen II. Marburg. 1893. p. 346.

2) W. WÄCHTER. Beiträge zur Kenntniss einiger Wasserpflanzen. Flora Bd. 83 1897. II. Weddelina squamulosa Tul. p. 382.

3) J. MILBREAD. Beitr. z. Kenntn. der Podostemonaceen. Inaug. Diss. Berlin 1904.

4) FRANZ MATTHIESSEN. Beiträge zur Kenntnis der Podostemaceen. Bibliotheca botanica. Heft 68. Stuttgart 1908.

here they are found more especially in the neighbourhood of the vascular bundles. In the flowers the secretory cells are found more especially in the spathella, the stamens and the wall of the ovary, whereas the ovules are free from them. In the haptera secretory cells are also to be found.

2. Oenone Staheliana. (This is a new species of which the description will shortly be published by me.) .

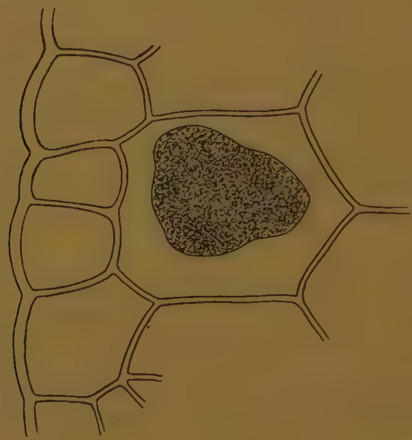

Fig. 1. Young leaf of Oenone Staheliana with subepidermal secretory cell in glycerine. Magn. 720 ×.

Here the secretory cells in the "gills" are mostly subepidermal as will be seen from figure 1, but in the leaf they may be found in other spots. In the stems the subepidermal position is very striking but besides they also accompany the vascular bundles. These are surrounded by starch-containing parenchyma and on the outer border of this tissue a certain number of long laticiferous tubes may be found.

3. Oenone Richardiana. About this species almost the same can be said as about the former one. In the "gills" a great many secretory cells are to be found, especially in the layer of cells bordering the epidermis, but also in other parts of the leaf and in the stem. In the flower they are present not only in the spathella and in the filaments but also in the wall of the ovary and in the stigmata.

4. Apinagia perpusilla. The same may be said about this species as about the last one. Especially in the leaves the secretory product is easily to be detected. One often gets the impression of it being some thick sticky liquid; so that, when cutting, it is often spread over the sections with the razor.

5. Tristicha hypnoides. Here the secretory cells are found more particularly near the margin of the leaf, as may be seen in figure 2. The small teeth of this margin consist of cells without chlorophyll, everyone of them containing a deposit of silica. These are bordered very often by secretory cells, which also contain chlorophyll; sometimes these are lying

in a single row, or this row is broken by ordinary cells as in our figure. A row of secretory cells is also present on both sides of the midrib.

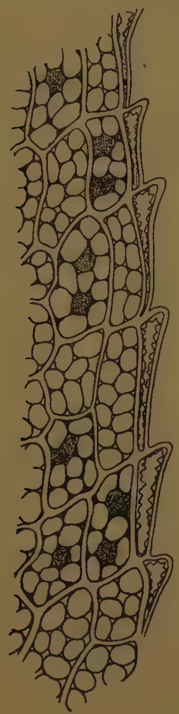

Fig. 2. Margin of a leaf of Tristicha hypnoides. In the teeth of the margin silica deposits; all the other cells have chloroplasts, but some have got besides these also the secretory product, which here has a brown colour. Magn. 1080 ×.

A more detailed study shows that in these cases we always have to do with living cells, also the long secretory channels are formed through the stretching of one single cell.

These cells may be stained red with borax carmine, brown with Iodine-solution. They show a positive Millon's reaction, and also a biuret-and a xanthoproteic reaction; consequently proteins appear to be present. With fixed preparations it can easily be shown by means of stains, e.g. heamatoxylin, that a number of nuclei are present as may be seen in figure 3, which refers to Oenone Richardiana. Hence in this respect those

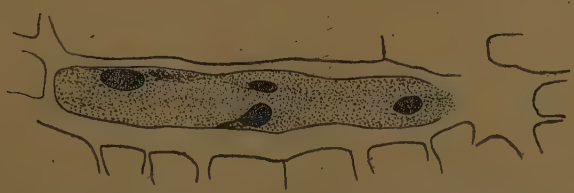

Fig. 3. Secretory channel in a stem of Oenone Richardiana with many nuclei. Fixation with Juel, staining with haematoxylin. Magn. 725 ×.

laticiferous tubes behave in the same way as other ones which have been investigated. This behaviour was first described by MELCHIOR TREUB.

The secretory product is insoluble in water, but soluble in alcohol,

chloroform, acetone, etc.; it may be coloured with alkanetpigment and with Sudan III. Consequently it was supposed that we have to do with some fatty or resiniferous substance. The green colour acquired a few days after treatment with copper acetate, makes it probable that it is some kind of a resin. But on account of our being so very ignorant about these plant products, it may be of some use to mention here the reactions which these resins did show after treatment with those reagents which were at our disposal in the jungle. The secretory product is soluble in glacial acetic acid, also after some time in concentrated sulfuric acid and in a 33 % solution of chromic acid; also caustic soda solution and ammonia act as a solvent. In a 60 % solution of chloral hydrate no real solution takes place, only the oily drops become more transparent. In preparations which had long been kept in glycerine, oily drops were found with a great number of cristalline needles showing double refraction. The sap extruding from plants of Mourera did distinguish itself by a strong resinous flavour.

Lastly, I must draw attention to the curious hairs which are to be found on the surface of the stems and leaves of Mourera; these hairs sometimes contain little drops in their cells which give the same reactions and generally look like the contents of the resiniferous cells. I could not say for certain whether these substances really are identical, more especially because they ought to be studied in the living state, which study can only be carried on in the jungle.

Now, concerning the principal question it can be said that a study of the living cells as well with Mourera as with the two species of Oenone, with Apinagia and Tristicha has yielded the same results. More especially the small cells of the "gills" or warts were investigated, because these parts could easily be brought under the microscope without much dissection.

Figure 4 represents such a secretory cell; a parietal layer of proto-

Fig. 4. Cell out of a young leaf of Oenone Staheliana; on the left hand the parietal layer of protoplasm is to be seen and the central vacuole with little particles or drops. On the right hand this same cell is plasmolysed in glycerin; the contents of the vacuole look like an oily fluid. Magn. 200 ×.

plasm may be seen and a mass of the secretory product in the centre of the cell. After treatment with glycerine plasmolysis did occur, as may be seen in the rigth hand part of the figure. The protoplasm has now contracted but the peripheral part is still to be seen, partly as thin threads. The secretory product has the appearance of a transparent oily mass.

This phenomenon which is very often observed in plasmolysis cannot be the result of glycerine entering the vacuole; for when accidentally a cell in a preparation is opened so that the secretory masses lie free, these show no alteration on the addition of glycerin. Generally, the conclusion could be drawn from these and other similar plasmolytic experiments that the secretory masses are lying in the cellsap; they are small drops, which can flow together and combine when they are drawn together.

In order to get a better insight into these phenomena, very young stages were investigated mostly in the spathella or in the "gills", so that as little handling as possible was necessary. In all cases, whether I used Mourera fluviatilis, Oenone Staheliana, Oenone Richardiana or Tristicha hypnoides, the result was always the same.

The first indication that one has to do with a secretory cell is the appearance of a few very small particles or little drops in the cellsap, which show a lively Brownean movement. Gradually, the number of these particles increases and at the same time their movements decrease till at last they stop entirely; it looks as if these small masses gradually flow together.

In figure 5 some stages of this development are shown in cells of

Fig. 5. Young cells from the warts of Mourera fluviatilis. On the right-hand side with two vacuoles, one without and the other with the beginning of the accumulation of secretory product; in the middle cell somewhat more of this substance has been formed, on the left hand a somewhat older stage. Brownean movement visible in every cell. Magn. about 400 ×.

Mourera fluviatilis. The figure on the right-hand side shows a very young stage, where two vacuoles may be seen in one cell; only in one of these a few particles of secretory product can be seen, the other one has only got watery contents. The middle figure shows a somewhat older stage, in which the Brownean movement was well visible. The same may be said of the left-hand figure which represents a somewhat older cell.

It was already said that in plasmolysing the small drops flow together. Very rarely the impression was given as if a new precipitate would arise during plasmolysis; but I rather think that this is generally not the case. It is much more probable that these secretory products take their origin in the cytoplasm and that afterwards they have to pass the tonoplast. When explanations are sought for the semipermeability of the plasmamembrane and more especially of the vacuolar membrane it will always be necessary to account for the fact that oily or resinous drops can pass these membranes.

The question might be put whether it is permitted to call the mass found in the secretory cells of the Podostemonaceae latex. Perhaps we would not do this so easily if no milky juice flowed out of the larger forms after some wound has been made. I agree at once that this fluid is not in every respect comparable with the latex of Hevea, but the question might be put if this same remark would not hold true for other milky fluids? Has not every latex some peculiarity of its own not to be found in that of other plants? A short time ago ULTEE [1]) has given a summary of our knowledge about the composition of latices. In accordance with his view I should like to retain the general name of latex as long as we are so extremely ignorant about the part which latex plays in the life-history of the plants; this name originated from the general custom of the language and it tells nothing about its significance. Then also the milky juice of the Podostemonaceae cannot be left out of consideration when we deal with latex. Consequently, in generalizing it may be said that the particles of the latex are lying in the cellsap, now that this has been made probable or proved for the laticiferous tubes or vessels of the Musaceae, of Euphorbia, Ficus, Carica and the Podostemonaceae. This does not exclude that in the outflow of latex there will certainly also be some protoplasm which extrudes and mixes with the cellsap.

At all events the position of the little drops or small particles in the interior of the cellsap makes it extremely improbable that these would afterwards again play a part in the chemism of the plant so that we are justified in considering them as excretory products.

Utrecht, February 1926.

Botanical Laboratory.

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[1]) A. J. ULTÉE: Melksappen. Pharmaceutisch Tijdschrift voor Nederlandsch-Indië. 2e Jaargang N⁰. 12 1925 p. 515.

Botany. — *"The results of the temperature-treatment in summer for the Darwin-Tulip."* Third Part. By R. MULDER and A. H. BLAAUW. (Communication N⁰. 19 Laboratory for Plant-physiological Research, Wageningen.)

(Communicated at the meeting of November 28, 1925).

§ 13. *Method in 1924—1925.*

In the first part (§ § 1—7) the results were described of 44 temperature-treatments applied in the summer of 1922 and observed from October 1922 to the flowering, spring 1923. In the second part (§ § 8—12) we worked out in detail the effect produced by the flower-forming growing-point after an exposure to the 11 temperatures (summer 1922) according to the fixed material.

Not until those results were known, it was possible to decide what further temperature-exposures should be compared and could be essential to a celerrimum, an optimum, the number of floral parts strongly dependent upon the temperature, etc. Besides it was necessary to observe, how the foliage developed, and the new lateral bulbs, i.e. the new main-bulb and the further smaller lateral bulbs, to how much therefore the produce of new bulbs amounted after those different temperature-exposures. For though superfluous, we remind of the fact that the entire Hyacinth-bulb increases in thickness in the first years, but that the bulb of the Tulip is completely used up, disappears and is replaced by a number of new bulbs. This number may be greater or smaller and the new bulbs may be more or less heavy. Those are results which are also taken into account in this paper, and give an additional impression of the far-reaching results of the temperature-treatment in the previous summer.

To form a connection with the treatment formerly applied, some treatments from digging to planting, a.o. the exposures to 9°, 20° and 26°, were repeated.

In fig. 15 a schematic representation has been given to render an impression as clear as possible of the 27 experiments.

The line of thought followed in the experiments starting in 9° is somewhat different from the one followed in the experiments started in 20° and 26°.

Those of 20° were chosen, because it had appeared that in 20° the flower-formation is most rapid in the beginning and progresses well; those

of 26°, not because the progress of flower-formation is slower and the size of the organs in formation is much smaller in the outset, but because that temperature yields very favourable flowers, the whorls of floral parts approach the normal number very closely, and because after that treatment in field-culture the flowering-period is normal, not accelerated.

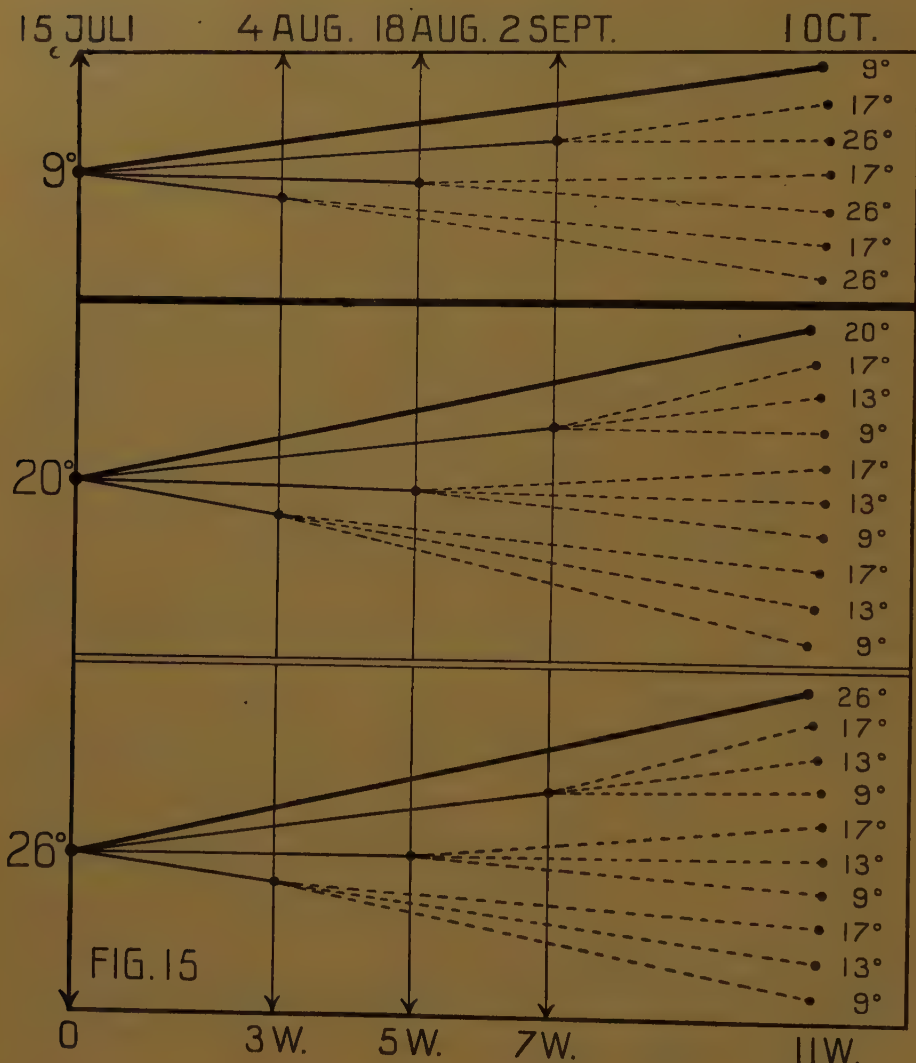

FIG. 15

The effect and difference were traced, if the bulbs were either permanently stored in 20° and in 26° in summer or put in a cooler place after 7 weeks, 5 weeks, or already after 3 weeks, viz. in 17°, 13° or 9° (see fig. 15).

The initial temperature 9° was chosen, because in 9° the *later* processes progress quickly and because in 9° (and 13°) the greater number of floral parts was formed. It was traced what differences arose, if the bulbs were not only kept permanently in 9°, but also when they were moved either into

17° or to 26° after 7 weeks, 5 weeks or even after 3 weeks till planting-time. These experiments starting in 9°, are in some sort opposed to those starting in 20° and 26°.

Of the previous 44 orientation-treatments in 1922, not only "9°, 20° and 26° permanently" were repeated in 1924, but also 9°, 20° and 26° *followed* by upwards of 4 weeks (Sept.) 17°. Altogether $44 + 27 = 71$ temperature-experiments were made, 6 of which were repeated as a control. Accordingly 65 different temperature-combinations were applied (not 68 as was mistakenly mentioned in the original Dutch first part § 1).

The experiments were started in July 1924 on the fifteenth, i.e. 5 days earlier than in 1922 (July 20). The number of foliage-leaves already in formation, amounted (nearly 2 or 3 on July 20, 1922), to only 1 or 2 on July 15, 1924. As will appear, in the different temperatures the number of usually upwards of 4 foliage-leaves is here likewise finished by the growing-point, before the flower-formation begins. Therefore the fact that the changes in the experiments were made in 1922 after 2, 4, 6 and a good 10 weeks, in 1924 after 3, 5, 7 and 11 weeks, was quite harmless.

In 1925 some most important temperature-combinations were repeated, the results of which will not appear until 1926 and cannot be published until then. In 1925 the Tulips were sent to us as early as July 1, an abnormally early date for Darwin-tulips. On cutting them it appeared that as to the progress of its leaf-formation the growing-point was in between July 20, 1922 and July 15, 1924 (see afterwards part IV). For an accurate comparison in such experiments the state of the growing-point should be examined from time to time, and all experiments to be compared ought to be commenced, when *e.g.* averagely 2 of the 4 (or 5) leaflets have been formed. After some routine the experiments may be started directly, provided we keep ourselves always well-informed of the initial state, and accordingly regulate the time of removing to an other temperature e.g. from 20° to 9° (see later), or from 26° to 17° as well as possible. The best thing is to judge from the internal state of the bulb whether the right moment for transmission has arrived.

For each of the 27 experiments 20 specimens were destined for field-culture. At the outset of the experiments (July 15, 1924) they were weighed out against each other, so that every group of 20 bulbs weighed 740 grams. From the tables it will be noticed, that the number of plants per experiment sometimes amounted to 19, 18 or 17, because, either through disease or falling off or the non-appearance of the stalk, the number of 20 was diminished. But the average found for a certain magnitude is always converted to 20 in order to enable us to compare the whole at a glance.

Besides groups of 10 bulbs, weighing 370 grams on July 15, from 9°, 20° and 26° were fixed in alcohol 96 % after 3, 5 and 7 weeks for a mutual comparison of these divergent temperatures.

Finally it may be desirable to add here a list of the loss of weight

observed in so divergent temperatures as 9°, 20° and 26°. It should be borne in mind that the hygrometric condition of the air round the bulbs, in spite of that divergent temperature, was about the same, viz. till Sept. 1. 70 to 80 % moisture of the air and next till the planting only about 50 to 60 %. It is very likely owing to this, *that the loss of weight in so divergent temperatures is fairly equal.* Secondly we wish to refer to the great difference with the Hyacinth where the loss of weight in about that same period and in the same hygrometric conditions amounts to at least 16 %, i.e. at least 2½ to 3 times as much.

TABLE 13. Loss of weight during exposure in the summer of 1924, to 9°, 20°, 26° (for hygrometric condition see text.)

Exposure:	Weight of 20 bulbs		Loss of weight in grams	Loss of weight in percents
	on July 15	on Sept. 29		
9°	740	690	50	6.8 %
20°	740	699	41	5.5 „
26°	740	693	47	6.4 „

(see some figures previously given: Literature 1923, 1924; we shall revert to this later in a special publication on the influence of the moisture in that period).

§ 14. *Coming up and coming into bloom.*

All this as far as the essential points are concerned, is summarized in tab. 14. The results on coming up and coming into bloom after the 27 treatments will be briefly discussed in connection with that table. As stated above in these and following tables, forming a summary of numerous measurements and counts, we wish to emphasize only those striking contrasts which, starting from such a uniform material of equal weight, cannot but be valuable.

Appearing above ground.

At the beginning of October the bulbs were planted very regularly, covered with 5 cms. of sand, growing in a very fine species of sand of the "Wageningsche Berg", in the large brick cistern (description see 1922 "Small building-constructions for physiological Cultivation-experiments"), with a fixed ground-water-level of 60 cms. below the surface.

On coming up of which a fairly accurate representation is given in the table in serial figures, the following features strike us:

TALBE 14. The order of succession of appearing above ground and coming into bloom.

Exposure	Order of succession of appearing above ground	Order of succession of flowering
11 w. 9°	1	1st, very unequal (April 23)
7 w. 9° + 4 w. 17°	5	
7 w. 9° + 4 w. 26°	8	some opening May 6
5 w. 9° + 6 w. 17°	5	
5 w. 9° + 6 w. 26°	9	completely closed May 6
3 w. 9° + 8 w. 17°	4	
3 w. 9° + 8 w. 26°	9	completely closed May 6
11 w. 20°	6	some opening May 6
7 w. 20° + 4 w. 17°	6	
7 w. 20° + 4 w. 13°	4	
7 w. 20° + 4 w. 9°	4	4th
5 w. 20° + 6 w. 17°	5	
5 w. 20° + 6 w. 13°	4	
5 w. 20° + 6 w. 9°	3	2nd
3 w. 20° + 8 w. 17°	4	
3 w. 20° + 8 w. 13°	4	
3 w. 20° + 8 w. 9°	2	1st, quite uniform (April 23)
11 w. 26°	7	completely closed May 6
7 w. 26° + 4 w. 17°	6	
7 w. 26° + 4 w. 13°	6	
7 w. 26° + 4 w. 9°	6	
5 w. 26° + 6 w. 17°	6	
5 w. 26° + 6 w. 13°	5	
5 w. 26° + 6 w. 9°	4	
3 w. 26° + 8 w. 17°	5	
3 w. 26° + 8 w. 13°	4	
3 w. 26° + 8 w. 9°	2	3rd very irregular bad group, great difference with 3 w. 20° + 8 w. 9°

1°. Most forward are the tulips which have been exposed to the coldest temperature (9°) during the whole summer (a good 11 weeks), which corresponds with the experience mentioned in part I. This is corroborated by the fact that the two experimental groups 3 w. 20° + 8 w. 9° and 3 w. 26° + 8 w. 9° succeed. These too had remained in 9° (Aug. 4 till Oct. 6) for a very long time. The third to show were 5 w. 20° + 6 w. 9°.

This is exactly as might be expected in the 20 experiments with 20° and 26°. But that for instance 7 w. 9° + 4 w. 17° lags decidedly behind is striking. This teaches us that especially the *after-treatment* in a low temperature as 9° is essential to the *celerrimal* coming up (showing of the tips) ; that in the *very first weeks*, i.e. as *first part of the treatment* a high temperature (especially 20°) scarcely causes a delay for the celerrimum many months later in coming up, provided a good low temperature follows.

2⁰. Observing the braces in the column concerned of tab. 14, we see once more emphasized in the 9°-experiments the fact which had been proved three times running, that after an *initial* treatment in 9° *the after-treatment in 26° is sure to give a considerably greater retardation than the after-treatment in 17°* with respect to the shooting of the flowerstalk.

3⁰. Observing likewise the treatments in 20° and 26°, we find that after 7 weeks 26° followed by 17°, 13° and 9° the coming up is the same in these three experiments and but very little quicker than after a "permanent 26°" exposure. But in all other cases there is no doubt but the after-treatment in 9° produces a *quicker* effect than in 17° and as a rule in 13°.

4⁰. The accelerating effect for the coming up in 9° is the stronger according as the preceding temperature was lower or lasted a shorter time (in 20° and 26°). For a better survey we cite from the column concerned the following data :

11 weeks 9°:	order of succession of appearing above ground	1.
3 w. 20° + 8 w. 9° :	,, ,, ,, ,, ,, ,, ,,	2.
3 w. 26° + 8 w. 9° :	,, ,, ,, ,, ,, ,, ,,	2.
5 w. 20° + 6 w. 9° :	,, ,, ,, ,, ,, ,, ,,	3.
5 w. 26° + 6 w. 9° :	,, ,, ,, ,, ,, ,, ,,	4.
7 w. 20° + 4 w. 9° :	,, ,, ,, ,, ,, ,, ,,	4.
7 w. 26° + 4 w. 9° :	,, ,, ,, ,, ,, ,, ,,	6.

5⁰. Finally we want to point out, that an initial treatment with 9° followed by 26°, e.g. 3 w. 9° + 8 w. 26° and even 5 w. 9° + 6 w. 26°, causes a later shooting than e.g. 7 w. 26° + 4 w. 17° and 5 w. 26° + 6 w. 17°.

We saw (also in part I), that permanently 9°, i.e. 9° in the first weeks and likewise in the weeks before planting, gives a celerrimum. The fact that 3 w. or 5 w. 9° followed by 26° are among the *latest* groups is not due to the initial low temperature, but particularly to the retardation the high temperature (26°) gives, *if* it is applied in the latter weeks before planting (in general after Aug. 15). Moreover the possibility exists that it is the succession of a rather low temperature as 9° and a high temperature as 26°, which causes the subsequent retardation. In connection with this we refer to what the progress of flower-formation has taught us (see part II fig. 3). From this we know — (we shall see it corroborated in § 16 by

experiments made 2 years later) — that the progress of the *flower-formation*, i.e. the *early* process, is *slower* in 9° than in 26°. Further it has repeatedly appeared from the above and from the previous papers (in fact just as with the Hyacinth), that if different parts of the flower have once been formed, a low temperature as 9° does have a celerrimal effect in the Tulip! *Thus an experiment with an initial 9°, then a higher temperature (e.g. 26°) is doubly retarding. On the contrary an experiment with an initial high temperature (especially 20°) for a short period followed by a low temperature (9°) is accelerating.*

We shall revert to this when discussing the coming into bloom, which will make it clear to us, why the knowledge of these details has some interest with a view to a further application and continuation of these experiments.

Order of succession of coming into bloom.

A great part of the groups flowered almost simultaneously (see tab. 14, last column) and most of these have not been mentioned with a serial number. Their flowering-period was normal for the Darwin-tulip. A few open rather late (11 w. 20° and 7 w. 9° + 4 w. 26°) and in some three groups all 20 flowers are still completely closed on May 6. Among these are the two groups which were the last to come up (serial number 9), viz. 5 w. 9° + 6 w. 26° and 3 w. 9° + 8 w. 26°. This allies perfectly with what was said above about the lengths of the shoots (coming up).

Of more consequence are the few groups which flowered earliest. These reveal, that in the after-effect in the field many months later the order of succession of flowering does not quite correspond with the order of coming up. Even *after months the after-effect is unequal* after the various treatments in summer. The differences however are not great.

The first to flower and simultaneous are 11 w. 9° and 3 w. 20° + 8 w. 9°. Compared with the time of coming up the latter has caught up 11 w. 9°. But the group 3 w. 20° + 8 w. 9° is strikingly uniform in shooting up and during the flowering (April 23), moreover the flowers are entire and regular. The group 9° however is very unequal in its flowers (April 23); various flowers are outwardly irregular and crooked on account of transitional formations between tepals and foliage-leaves, which corroborates the findings on some 10 individuals 2 years ago (See first part, visible here and in fig. 2). That likewise the foliage was more unfavourable, we discussed in part I and we shall further illustrate in this part in § 17, table 25.

The most important conclusion from table 14 is, that 3 w. 20° succeeded by 9° is as celerrimal as 9° permanently, but considerably better.

So *3 w. 20° + 8 w. 9° (till the end of the first week of Aug. 20° succeeded by 9° till planting-time) is the most favourable base to experiment on early flowering of Darwin-tulips.* The results of the experiments on

early flowering (founded on that base) will be communicated in some time. It will however be necessary to compare them next year to a few groups with an other temperature-treatment in summer than these 27 treatments in summer.

At present a treatment in summer of 20° till the beginning of Aug. succeeded by 9° is the best starting-point for early flowering and favourable flowers combined.

But properly speaking it is wrong to continue mentioning dates at which the transition from one temperature to an other is preferably made. For we already pointed out, that the condition of the growing-point at the period of lifting may vary greatly, e.g. in July 1925 it was about a fortnight in advance of 1924 and 1922 in its leaf-formation. *"On lifting"* we say emphatically, for when once lifted and taken to special temperatures (esp. 20°) leaf- and flower-formation progress rapidly (see 2nd part and fig. 3). *Though the application requires a little more trouble, it is much more rational and sure to give in stead of the point of time the stage (and determine it by applying), at which the bulbs should get a change of temperature.*

As will be further shown in § 16, tab. 22, the bulbs, when on Aug. 4, 1924 they were removed from 20° to 9°, were about in stage III, i.e. the outer whorl of tepals is completed, the inner in formation.

And so it appears that while 9° and 3 w. 20° + 8 w. 9° flower simultaneously, it is essential for early flowering when and after what preliminary treatment the transmission occurs. On continuing after 3 w. 9° in 9° a leaflet has been added (see table 21), but the transition takes place during stage I the consequence of which is much more irregular and partly even less favourable flowers than on removal after 3 to 4 w. 20° into 9°, or *putting it more accurate after the flower has first been allowed to reach Stage III.* There is no reason whatever why the flower should be ready; if only most of the tepals have been formed a removal to 9° is desirable. If they are left in 20° till the flower has just been completed (stage VII, Aug. 18, 1924, see tab. 22), we have the case 5 w. 20° + 6 w. 9° from our experiments and find that they are advanced (see tab. 14) in the field, yet they are *a little* later in coming into bloom. On forcing in-doors (e.g. hothouse) this difference in time would probably be evident. *As far as we know at present,* a removal from 20° to 9° is allowed as soon as the flowers are in stage III,if need be IV (stamina in formation).

Meanwhile as mentioned above, some other temperature-treatments in summer were tried with a view to the "early-flowering".

Finally we want to draw the attention to 3 w. 26° + 8 w. 9°. From table 22 we may see, that in this case just as after 3 w. 9° the growing-point is still forming leaves when transmitted to 9° and the result is (see table 14) that the flowering (in consequence of the long after-treatment in 9°) is rather early ("3rd"), but forming a very irregular, bad group, a great difference with 3 w. 20° + 8 w. 9°. And this latter feature is perfectly comprehensible, now that through extensive fundamental experiments (see

part II, fig. 3 and figs. 4—14) we know that in 20° after a quick completion of the leaf-formation the flower-formation is most rapid and on removal of the bulbs to 9° has already much advanced.

§ 15. *On the number of foliage-leaves and floral parts after these 27 treatments in summer.*

Let us first discuss the above in connection with table 15. Besides we refer to the number of floral parts and the combinations of the numbers

TABLE 15. Number of foliage-leaves and floral parts as an average per 20 plants.

Exposure	Leaves	Tepals	Stamina	Carpels	Total number of floral parts
11 w. 9°	4.25	8.35	8.32	4.10	20.77
7 w. 9° + 4 w. 17°	4.25	8.84	8.47	4.27	21.58
7 w. 9° + 4 w. 26°	4.1	9.25	8.15	4.15	21.55
5 w. 9° + 6 w. 17°	4.15	8.85	7.85	3.70	20.40
5 w. 9° + 6 w. 26°	4.31	7.52	6.73	3.73	17.98
3 w. 9° + 8 w. 17°	4.15	8.20	7.35	3.25	18.80
3 w. 9° + 8 w. 26°	3.84	6.57	6.57	3.47	16.61
11 w. 20°	3.95	7.15	7.00	3.20	17.35
7 w. 20° + 4 w. 17°	4.05	7.00	7.00	3.31	17.31
7 w. 20° + 4 w. 13°	3.89	6.50	7.44	3.11	17.05
7 w. 20° + 4 w. 9°	4.0	7.00	6.89	3.26	17.15
5 w. 20° + 6 w. 17°	3.7	6.50	6.55	3.10	16.15
5 w. 20° + 6 w. 13°	3.75	6.55	6.57	3.05	16.17
5 w. 20° + 6 w. 9°	4.0	6.85	6.65	3.05	16.55
3 w. 20° + 8 w. 17°	4.11	6.94	6.87	3.12	16.93
3 w. 20° + 8 w. 13°	3.8	6.80	6.70	3.15	16.65
3 w. 20° + 8 w. 9°	3.65	6.50	6.55	3.05	16.10
11 w. 26°	4.15	6.10	6.15	3.65	15.90
7 w. 26° + 4 w. 17°	4.1	6.10	6.40	3.75	16.25
7 w. 26° + 4 w. 13°	4.04	6.14	6.19	3.38	15.71
7 w. 26° + 4 w. 9°	4.14	6.19	6.33	3.61	16.13
5 w. 26° + 6 w. 17°	4.40	6.65	6.50	3.60	16.75
5 w. 26° + 6 w. 13°	4.52	6.85	7.19	3.38	17.42
5 w. 26° + 6 w. 9°	4.35	6.75	7.20	3.50	17.45
3 w. 26° + 8 w. 17°	4.1	7.40	7.05	3.20	17.65
3 w. 26° + 8 w. 13°	4.7	8.50	7.75	3.70	19.95
3 w. 26° + 8 w. 9°	4.52	9.26	9.10	4.05	22.41

of floral parts fully treated in the first part (§ 5) for the experiments 1922—1923. The following pages, a result of experiments in 1924—1925, should be considered (though there are 21 new combinations among them) a control of part of the results found and discussed there. All figures from the table are either an average from 20 plants flowering in the grounds or they have been converted to a number of 20, when the group consisted of a smaller number either by mistake or on account of a single bad individual.

As to *the number of foliage-leaves* amounting to 1.3, when the experiments were started (July 15), — it is evident again that in all treatments the leaves are the first to be completed. Here too there is but little difference as to the final number of foliage-leaves under the influence of the temperatures. In 1922 the average was increased from 2.3 to 4.3 from July 20, so 2 leaves were added. In 1924 the average 1.3 of July 15 was increased to upwards of 4.0. This means, that just as before the temperature-treatment has little influence on the final number of foliage-leaves. May be somewhat, for: With the figures concerning the experiments starting in 9° and 20°, we find as a mean of those averages, i.e. of ca 17 $\times$ 20 = ca *340* plants: 4.0, with the experiments starting at 26° (total of ca *200* plants): 4.3.

In that latter series there never occurs in a group an average under 4 foliage-leaves; moreover the highest averages are attained (4.52—4.52—4.7) in this series which never occur in the series starting with 9° and 20°.

So it appears that for the number of foliage-leaves a high temperature (26°) for a few weeks succeeded by a low temperature (especially 13° and also 9°) has some effect. Since however no effect of it is noticed (see § 17) on the assimilation-result (probably due to the fact that in those treatments the leaves are among the narrower), this slight difference has no practical value and we shall let the matter rest in this paper. The fact that 13° (for a long period) has a rather favourable effect on the number of leaves, we already stated in part I (§ 5, tab. 3).

From the number of floral parts (tab. 15) the following facts, which have already partly been emphasized by heavy type and by connecting braces, may be concluded:

1°. In most cases, when 9° precedes and especially when it has been continued for a short time, the number of floral parts is greater, when an exposure to 17° follows than an exposure to 26°. Only when 9° has been applied for a long time (7 weeks) there arise in an after-treatment in 26° equally high numbers as in 17°; evidently (see fig. 3 part 2) because in that case the flower-formation is so far advanced in 9°, that the short after-treatment has little effect on this number.

2°. The total number of floral parts (and also that of the individual whorls) is high after a long exposure to 9° and only after 3 w. 9° + 8 w. 26° the average number greatly decreases. That might be expected, for after 3 w. 9° (on Aug. 4) the leaf-formation is by no means ready (stage I,

see e, g tables 21 and 22) and 26° has to bring about the flower-formation. All these little details show the great importance of ascertaining these events thoroughly and extensively. How much time and trouble this may require, in the long run, it is the only way of getting a sure basis.

3º. The experiments started in 20° do not yield figures forming such striking contrasts as those started in 9° and 26°. This stands to reason, because already after 3 weeks 20° the flower-formation (Aug. 4, stage III) is well advanced, which is by no means the case in 9° and 26°. Yet there is something peculiar in this table. Though the differences are not great on account of the reason mentioned, yet it cannot be denied (see especially the last colum) that after the flower in 20° has progressed more or less, the number of floral parts is somewhat smaller, when the after-treatment occurred in lower temperatures. So we find about the lowest amount in 3w. 20° + 8w. 9°, the highest average in 11w. 20° (= 3w. 20° + 8w. 20°).

To these two extreme treatments of this series may surely be attached some value and it might be expected after 3w. 20° (stage III), that the succeeding temperature would make its influence felt, e.g. on the whorls of stamens, consequently in the final number of stamens.

So far we should have expected a larger number of floral parts in 9° after Aug. 4, whereas we see, that a removal to 9°—13°—17°—20° (the upper) after 3 weeks yields a slight, yet regular increase.

We cannot but conclude that after a short exposure to a moderately high temperature as 20° during which the period of flower-formation soon sets in, a further exposure to 17° to 20° yields a slightly larger number of floral parts than might be expected on removal to a low temperature (9°); may be because the flower-formation is far advanced and in that case a transfer to a low temperature causes the flower-formation to be rather quickly completed and the growing out to be promoted, not the formation of the floral parts far above the normal base. However this may be, that early removal to 9° is certainly not injurious: The other floral parts are finished as well and in § 11 we already saw that the combination of a short exposure to 20° followed by 9°, guarantees a ready formation, a rapid shooting and fine uniform flowers. Here we see that the number of those floral parts after that treatment is but little above the normal base (15) [1].

4º. Nevertheless we should be careful, especially with slight differences (as in the series starting in 20°) in attaching value to those differences.

So in table 16 the number of bulbs and their sum has been given again together with the mean error of some seven important and divergent treatments. In this table the value of the differences given in table 15 may be satisfactorily tested. The number does not exceed 20 and we find, e.g. for the average sum of all floral parts after 11 w. 20° (17.35) a mean error of ca 0.42. In the material of two years before after the same permanent

[1]) To this we shall revert in an article on early flowering.

TABLE 16.

Exposure	Tepals M	m	Stamens M	m	Carpels M	m	Floral parts M	m
1 w. 9°	8.35	± 0.25	8.32	± 0.31	4.10	± 0.16	20.77	± 0.55
1 w. 20°	7.15	± 0.22	7.00	± 0.18	3.20	± 0.09	17.35	± 0.42
1 w. 26°	6.10	± 0.07	6.15	± 0.08	3.65	± 0.11	15.90	± 0.19
7 w. 26° + 4 w. 17°	6.10	± 0.07	6.40	± 0.14	3.75	± 0.12	16.25	± 0.22
3 w. 26° + 8 w. 17°	7.40	± 0.27	7.05	± 0.23	3.20	± 0.09	17.65	± 0.50
3 w. 26° + 8 w. 13°	8.50	± 0.30	7.75	± 0.32	3.70	± 0.13	19.95	± 0.58
3 w. 26° + 8 w. 9°	9.26	± 0.41	9.10	± 0.32	4.05	± 0.16	22.41	± 0.58

exposure to 20° M was calculated to be 17.20, which tallies very well. Then in the larger number of observations (54) the mean error amounted to ca 0.27, which is also in accordance with the different number of observations now (20) and at that time (54).

5⁰. Even more convincing the figures are in the series of experiments starting in 26°. A long exposure to the highest of the temperatures hitherto applied gives the smallest number of floral parts. After 11 and 7 weeks 26° for instance an average is found of 15.90—16.25—15.71—16.13. As (see tab. 16) for the number of floral parts e.g. in 11 w. 26° and 7 w. 26° + 4 w. 17° the mean error amounts to at least ± 0.19 (and this mean error is particularly slight compared to other groups) there cannot be attached any value to these differences and the total number of floral parts after those 4 treatments amounts to ca 16.0. (Two years before: after exposure to 25½° 16.35 ± 0.22 and after exposure to 28° 15.90 ± 0.37, so a very slight deviation). On our considering table 22, it may be understood, that a removal to (26°), 17°, 13° or 9° on Sept. 2, 1924 has no influence on the number of floral parts, because on Sept. 2 the number of floral parts had already been fixed in nearly all flowers.

But if we observe 3 w. 26°, it is evident how much a lower temperature advances the increase of *all* floral whorls (see the three lower rows with braces). In table 17 we wish to give again the *total* number of floral parts of that treatment of table 16, because that observation is most conspicuously represented by it and it corroborates what was repeatedly found before: *a low temperature of 9° (and according to the earlier experiments also of 13°) gives rise to the greatest number of floral parts in single ("not full") tulips, whereas high temperatures approximate the typical morphological number most.*

A distinct rise is to be observed (to the left), as well if the mean error is taken into account. To the right has been placed the average found in 1922, when the flower was completed in those four temperatures. Considering the mean error, 22.41 (to the left) and 21.59 (to the right)

TABLE 17. Total number of floral parts.

Formed in 1924	M	m	Formed in 1922	M	m
3 × 26° + 8 × 26°	15.90	± 0.19	17°	19.68	± 0.24
3 × 26° + 8 × 17°	17.65	± 0.50	13°	21.55	± 0.26
3 × 26° + 8 × 13°	19.95	± 0.58	9°	21.59	± 0.58
3 × 26° + 8 × 9°	22.41	± 0.58			

might not be taken as positive differences, but if 17°, 13°, 9° (to the right) are compared to the same (to the left) which have been preceded by 3 w. 26°, it appears that the contrast between 17°, 13° and 9° is greater, when 26° has preceded. This is the more striking as after 3 weeks (Aug. 4, 1922) the growing-point is completely engaged in forming leaves. The total impression we get is, that 3 × 26° + 8 × 9° gives rise to a somewhat greater number of floral parts per flower than permanently 9° or 13°. In part IV we shall be able to decide this question more accurately on a larger number of flowers and we shall revert to the subject there. Here we shall abide by the above statement in italics, a corroboration of our previous experiences with the material of 1922.

We have dwelled at length upon tab. 15, but it should be remembered, that in this table ca 2700 counts have been represented by their averages.

Just as in part I (§ 6, tab. 8) we wish to subject *the combinations of the numbers of floral parts* to a closer examination. These have been collected in tables 18, 19 and 20 for the combinations 6—6—3 to 8—8—4. The 27 treatments gave us 530 numerable flowers. 400 of these 530 flowers were included in those 18 combinations. The 130 flowers outside these 18 combinations exceeded them all but one (772 after 3 w. 9° + 8 w. 17°). Of course we now find a higher percentage among those combinations than at the time, when a great many more treatments were applied yielding high figures. We should averagely find at most 23 of these 400 cases in one of the 18 combinations by perfectly equal division. As a great many have 6—6—3 and 7—7—3, the normal number possible for the remaining 16 combinations is much smaller (13). Let us first consider the frequence of the 18 combinations from all 27 experiments in table 18.

1°. The combination 6—6—3 (149×) is by far the most frequent in these experiments, next as rather frequent follow 7—7—3 (54×), or 7—7—4 (26×) and 8—8—4 (32×) or 6—6—4 (32×). This tallies perfectly with the results of the 44 treatments 2 years before (§ 6 tab. 8). Since we have now generally chosen other temperatures, many with 26° and none e.g. with 13°, 17°, — the number with 6—6—3 is great, with 8—8—4 not very numerous though rather conspicuous, and with 7—7—3

again rather large on account of the many experiments on flower-formation in 20°. The above is in perfect correspondence with the results previously found and quoted. Nevertheless we shall repeat some of these results in part IV with a greater number per experiment, since from an experimental-morphological point of view they are so very remarkable.

2⁰. When the initial exposure to 9° lasted only 5 or 3 weeks, the after-treatment in 26° brings on a much greater number of flowers *belonging to* these combinations (and the combination 6—6—3 is much more frequent) than in an after-treatment with 17°, as might be expected (see table 22).

TABLE 18.

Exposure: / Combination:	Frequence from all 27 experiments together	11 w. 9°	7 w. 9° 4 w. 17°	7 w. 9° 4 w. 26°	5 w. 9° 6 w, 17°	5 w. 9° 6 w. 26°	3 w. 9° 8 w. 17°	3 w. 9° 8 w. 26°
663	**149**	2	—	—	—	3	1	12
664	**32**	—	—	—	—	2	—	—
673	16	—	—	—	—	1	—	—
674	12	—	—	—	—	—	—	—
683	3	—	—	—	1	—	—	—
684	0	—	—	—	—	—	—	—
763	21	—	—	—	1	1	1	—
764	6	—	—	—	—	—	—	—
773	**54**	—	2	—	—	1	1	1
774	**26**	—	—	—	—	2	—	—
783	5	—	—	—	—	—	—	—
784	3	—	—	—	—	—	—	—
863	3	—	—	—	—	—	2	—
864	2	—	—	—	—	1	—	—
873	15	—	—	—	—	1	2	—
874	8	—	—	1	—	1	—	2
883	13	1	—	—	1	—	—	—
884	**32**	4	1	—	2	—	4	2
Within these 18 combinations:		7	3	1	5	13	11	17
Number of flowers counted:		20	19	20	20	19	20	19

When however the transition from 9° to 9°—17°—26° does not occur until after 7 w. (Sept. 2, 1924) we notice exactly the reverse and 7, 3 and 1 flower are respectively found within those 18 combinations (of each group of ca 20 flowers).

30. On our considering table 19 giving experiments starting with a shorter or longer period in 20°, in which already after 3 w. about half the number of floral parts have been formed, it strikes us that these methods of treatment provide an important share of the combinations 6—6—3

TABLE 19.

Exposure: / Combinations:	11 w. 20°	7 w. 20° 4 w. 17°	7 w. 20° 4 w. 13°	7 w. 20° 4 w. 9°	5 w. 20° 6 w. 17°	5 w. 20° 6 w. 13°	5 w. 20° 6 w. 9°	3 w. 20° 8 w. 17°	3 w. 20° 8 w. 13°	3 w. 20° 8 w. 9°
663	6	7	10	5	9	7	8	3	6	11
664	—	—	—	—	—	—	—	—	—	—
673	1	1	1	1	2	2	—	2	—	1
674	—	1	—	—	1	—	—	—	—	—
683	—	—	—	—	—	—	—	—	1	—
684	—	—	—	—	—	—	—	—	—	—
763	—	1	1	3	1	1	2	1	4	—
764	—	—	—	—	—	—	—	—	1	—
773	2	1	2	5	4	7	7	5	3	6
774	1	1	—	—	1	1	—	—	—	—
783	1	—	—	1	—	—	—	—	1	1
784	—	—	1	1	—	—	—	—	—	—
863	—	—	—	—	—	—	—	—	—	—
864	—	—	—	—	—	—	—	—	1	—
873	3	—	—	—	1	1	—	2	—	—
874	—	—	—	—	—	—	1	1	—	—
883	3	2	—	—	1	—	1	1	1	—
884	2	3	1	3	—	—	—	1	1	—
Within these 18 combinations	19	17	16	19	20	19	19	16	19	19
Number of flowers counted:	20	19	18	19	20	19	20	16	20	20

(72×); that the combination 6—6—4 never occurs in 10 experiments (187 flowers); that occasionally the rather uncommon combinations 6—7—3 (11×) and 7—6—3 (14×) occur; that especially the combination 7—7—3 is found (42× on 187 flowers, while it occurs altogether 54× in all 530 flowers).

40. In connection with table 20, experiments starting with a shorter or longer period in 26°, it may however be observed, that in this case the combination 6—6—4 is rather frequent (30×; in all experiments 32×).

TABLE 20.

Exposure / Combination:	11 w. 26°	7 w. 26° 4 w. 17°	7 w. 26° 4 w. 13°	7 w. 26° 4 w. 9°	5 w. 26° 6 w. 17°	5 w. 26° 6 w. 13°	5 w. 26° 6 w. 9°	3 w. 26° 8 w. 17°	3 w. 26° 8 w. 13°	3 w. 26° 8 w. 9°
663	6	5	13	10	8	6	5	5	1	—
664	11	7	5	5	1	—	1	—	—	—
673	1	—	—	—	—	1	1	—	—	1
674	—	4	1	3	—	—	2	—	—	—
683	—	1	—	—	—	—	—	—	—	—
684	—	—	—	—	—	—	—	—	—	—
763	—	—	—	—	1	—	2	1	—	—
764	—	—	—	—	2	—	—	2	1	—
773	—	—	—	—	—	6	2	1	—	—
774	2	2	1	—	6	4	2	—	1	—
783	—	—	—	—	—	—	—	1	—	—
784	—	—	—	—	—	—	1	—	—	—
863	—	—	—	—	—	—	—	—	1	—
864	—	—	—	—	—	—	—	—	—	—
873	—	—	—	—	—	—	—	4	1	—
874	—	—	—	—	—	—	—	—	2	—
883	—	—	—	—	—	—	—	—	1	1
884	—	—	1	1	—	—	1	2	3	—
Within these 18 combinations:	20	19	21	19	18	17	17	16	11	2
Number of flowers counted:	20	20	21	21	20	21	20	20	20	19

but 6—7—3 as usual is exceptional; that the combination 7—7—4, otherwise rather uncommon, is somewhat more frequent here than the combination 7—7—3 which is rather frequent in the previous table and in general; that the definite numerical groundplan 6—6—3 repeatedly occurs, in 5 w. 26° and especially after 3 w. 26° (stage I) the less according as the subsequent temperature is lower. So, to mention an extreme, 3 w. 26° followed by 9° behaves altogether as in the low temperature, only 2 of the 19 flowers for instance being in these 18 combinations, all the rest above them.

On account of the slight number of observations found for each square by this division, we shall not dwell upon this subject any longer. There are figures among them we might wonder at. But the number of observations distributed over these squares is too slight for us to decide whether all those slight deviations may indeed be attached any value to. Therefore we have restricted ourselves to mentioning some results from tables 18, 19 and 20, which mainly corroborate the previous results of two years before.

§ 16. *On the progress of the flower-forming period in 9°, 20° and 26° in the summer of 1924.*

Just as was done in part II for the 11 temperatures (in 1922), we have traced the condition in three divergent temperatures 9°—20°—26° on fixations of July 15 (beginning), Aug. 4, Aug. 18 and Sept. 2, i.e. after 3, 5 and 7 weeks. In the above we availed ourselves occasionally of tables 21 and 22, given in this § 16. We shall be brief with respect to these tables, since they give the result in concise, though satisfactory form.

Table 21 confirms, that the formation of the last foliage-leaflets (13) in progress on July 15 (on 10 bulbs), is already finished after 3 weeks in 20° (43), while table 22 shows that the flower-formation too is far advanced, and table 23, that the outer foliage-leaf has an average length of 1.90 mm., that on the contrary according to the tables mentioned both the low temperature of 9° and the high temperature of 26° lag far behind 20°, especially with respect to the length of the young foliage-leaves.

According to table 22 the leaf-forming period is finished for 9° and 26° on Aug. 18, just as was the case 2 years before; but 9° lags somewhat behind 26° (on Aug. 18 and Sept. 2, 1924, just as in 1922). The only difference with 1922 is, that whereas then the room was kept at 25½°, in 1924 at 26°, the flower-formation in 1924 was somewhat slower in progress than in 1922, which cannot very well be due to that difference of half a degree. Yet it is true (see part II fig. 3 on Aug. 18 and Sept. 1), that a difference of 25½° and 28° (2½°) makes a great difference at *that* time.

On observing the length of the first foliage-leaflet, already previously formed, we see from tab. 23 that between Aug. 18 and Sept. 2 9° and 26° come up strongly with 20°, especially 9°, in which the foliage-leaflet has attained the same length as in 20°.

TABLE 21. Number of foliage-leaves in formation on 10 bulbs.

July 15, 1924. Beginning of the experiments	August 4	August 18	September 2	Exposure
13	23	38	41	← 9°
	43	42	40	← 20°
	21	38	44	← 26°

TABLE 22. The stage in which the growing-point is on exposure to 9°, 20° and 26°.

July 15, 1924. Beginning of the experiments	August 4	August 18	September 2	Exposure
I	I	II+	V à VI	← 9°
	III—	VII	(VII)	← 20°
	I	III—	VII—	← 26°

TABLE 23. Length of the first foliage-leaflet formed, at the outset and after exposure to 9°, 20°, 26°, in mms.

July 15, 1924 at the beginning	August 4	August 18	September 2	Exposure
0.25	1.05	2.5	7.3	← 9°
	1.90	3.9	7.3	← 20°
	0.38	1.6	3.1	← 26°

TABLE 24. Average number of floral parts after exposure to 9°, 20°, 26°.

Sept. 2, 1924. Exposure:	Tepals	Stamens	Carpels
9°	8.3	10	—
20°	6.7	6.8	3.2
26°	6.1	6.3	3.2

Finally tab. 24 gives the average number of floral parts in formation on Sept. 2, 1924. In 9° we see, that the carpels are not yet in formation (cf. tab. 22: stage V to VI).

As to the number of tepals and stamens, it is again corroborated, that in 20° a few more are formed than in 26° (close to the base 6—6—3), but

that in 9° the floral parts are much more numerous than in 20° (and of course in 26°). Just as in table 16, previously discussed, it appears according to the material of 1924, that it may by no means be asserted, that in 9°—20°—26° this is more common with the tepals than with the whorls of stamens, as seemed to be the case in the material of 1922.

§ 17. *The produce of new bulbs after 27 modes of temperature-treatment in the previous summer.*

In this § there will be discussed what has been summarized in table 25 every experiment and every figure constituting a result in 1925 of groups of about 20 Tulips treated in 1924. These data are new. They were not traced on the material 2 years before, because then per experiment only 10 specimens were brought into bloom in the field.

1°. In column II we find as a certain standard for the assimilating-surface the average *width* of *the lower* (outer first,) *leaf*, in order to get a sure comparison with the yield of new bulbs, taking the place of the old bulb treated and planted, the reserve-food of which is quite exhausted (as contrasted with the bulb of the Hyacinth). It is evident, that *a long period in 9° is injurious to the leaf-width* and we may safely say for the assimilating surface. We may add that the very groups with the narrowest foliage were the first to wither, turn reddish and die. The worst in this respect was 11 w. 9°; the leaf is broader according as the exposure to 9° was shorter, but *always* better when exposed afterwards to 17° than to 26°. Likewise in the further experiments starting in 20° and 26° (total 6×), the after-treatment in 17° proves more favourable to the width of the leaf than in 13°, the latter better than in 9°. This is reciprocally corroborated.

In heavy type the experiments have been printed, yielding an average width of leaf above 100 mms. Though a continuous exposure to 26° gives excellent foliage, it appears on the whole, that an after-treatment in 17° is favourable with respect to the leaves, that when 17° follows, a preliminary exposure to 26° is surely not less favourable than to 20°.

7 w. 26° + 4 w. 17°, which we use for field-culture, is among the highest averages (110 mms.) twice as broad as after 11 w. 9°. The treatment 3 w. 20° + 8 w. 9°, which — at least hitherto — we have tried as the best preliminary treatment for early flowering, produces rather narrow leaves (ca 73 mms.), but since we aim at an early favourable bloom, the assimilating surface and the further yield is of little consequence.

2°. In those further columns the weights of *20 new main bulbs* column III have been given (the old main bulbs, received from the grower, weighed 740 grams per 20 in all experiments) [1]).

Further we find in column IV: the weights of all remaining bulbs in grams, most of them originated in the axils of other scales found more to

[1]) With this § 17 R. MULDER's research to be published later: "The periodical development of the Darwin-Tulip", should be consulted.

the outside, in column V the joint weight of these main- and further lateral bulbs, which further lateral bulbs will be distinguished from the main bulb

TABLE 25. Widths of leaves and yield of new bulbs.

I. Treatment	II. Width lower leaf (average of about 20 spec.)	III. Weight 20 main bulbs in grams	IV. Weight remaining bulbs from 20 old bulbs in grams	V. Joint weight main and secondary bulbs (from 20 old bulbs in grams)	VI. Number of bulbs formed (on 20 old bulbs)	VII. Weight of the 20 largest secondary bulbs (originated from 20 old bulbs)
11 w. 9°	55	610	419	1029	82	233
7 w. 9° + 4 w. 17°	71	694	652	1346	105	301
7 w. 9° + 4 w. 26°	63	560	560	1120	91	266
5 w. 9° + 6 w. 17°	81	700	690	1390	108	330
5 w. 9° + 6 w. 26°	77	632	**803**	1435	**120**	**338**
3 w. 9° + 8 w. 17°	96	**778**	719	**1497**	102	**339**
3 w. 9° + 8 w. 26°	93	507	**785**	1292	**124**	**335**
11 w. 20°	96	583	720	1303	110	318
7 w. 20° + 4 w. 17°	**103**	**840**	516	1356	87	295
7 w. 20° + 4 w. 13°	99	695	532	1227	86	271
7 w. 20° + 4 w. 9°	87	684	327	1011	73	229
5 w. 20° + 6 w. 17°	**108**	711	626	1337	98	313
5 w. 20° + 6 w. 13°	99	**740**	475	1215	78	279
5 w. 20° + 6 w. 9°	82	722	335	1057	75	184
3 w. 20° + 8 w. 17°	**110**	**745**	**792**	**1537**	**119**	**330**
3 w. 20° + 8 w. 13°	89	690	422	1112	83	252
3 w. 20° + 8 w. 9°	73	671	414	1085	75	246
11 w. 26°	**107**	587	**877**	**1464**	**121**	**385**
7 w. 26° + 4 w. 17°	**110**	692	**746**	1438	105	**340**
7 w. 26° + 4 w. 13°	**104**	**737**	689	1426	101	**335**
7 w. 26° + 4 w. 9°	89	489	**775**	1264	**122**	316
5 w. 26° + 6 w. 17°	**107**	694	662	1356	106	294
5 w. 26° + 6 w. 13°	87	690	717	1407	104	318
5 w. 26° + 6 w. 9°	75	528	578	1106	99	270
3 w. 26° + 8 w. 17°	**105**	**796**	**743**	**1539**	**120**	328
3 w. 26° + 8 w. 13°	78	665	567	1232	103	277
3 w. 26° + 8 w. 9°	64	637	512	1149	90	258

as secondary bulbs. Accordingly that column gives *the weight in bulbs, taking the place of the old main bulbs of a joint weight of 740 grams.* In any case we see a gain in weight in the total amount of the bulbs after each exposure.

Column VI gives the *number* of bulbs originated (main bulbs included). And finally to get an impression whether the secondary bulbs (so main bulb excluded) are of any value for propagation, column VII gives the joint weight of *the 20 largest secondary bulbs* (yielded by 20 bulbs planted).

3°. We shall have to revert to this table 25 (after completing part IV), which contains many things interesting for growers. The most striking results are already emphasized by braces and bold type.

A large leaf-surface, i.e. large assimilating surface, often goes together with heavy weights of main and (or) secondary bulbs (e.g. 7 w. 20° + 4 w. 17°, — 3 w. 20° + 8 w. 17°, — 11 w. 26°, as to the secondary bulbs — 7 w. 26° + 4 w. 17° moderate — 7 w. 26° + 4 w. 13° moderate — 3 w. 26° + 8 w. 17°). *In every respect* (according to all columns) *there is a correspondence between leaf-surface and produce after 3 w. 20° + 8 w. 17° and 3 w. 26° + 8 w. 17° — 7 w. 20° + 4 w. 17° yields a great weight of new main bulbs* (840 grams!) the weight and number of the other bulbs remaining slight. By far *the greater weight in secondary bulbs* (877 grams column IV) and moreover undoubtedly *the greater weight of the 20 largest secondary bulbs* (385 grs. p. 20 bulbs column VII) is yielded by 11 w. 26°, but this goes together with a rather slight weight of the main bulbs (587 grs. per 20 bulbs). Large leaf-width and large produce are least in accordance in 5 w. 26° + 6 w. 17° and e.g. 3 w. 9° + 8 w. 17°, but in the main (in the best and the worst individuals) the connection is evident.

With regard to *application* with respect to the yield of bulbs, we see that the temperature-treatment influences the produce of new bulbs to a high degree. Though it is not devoid of interest, that this yield may be judged in the main from the leaf-width (assimilation-surface), yet in practical application the final produce is the great thing. And now it depends, whether *big main-bulbs are especially preferred* (as after 7 w. 20° + 4 w. 17°), and the weight and number of the secondary bulbs are of little consequence; — or *that plenty of secondary bulbs of a relatively heavy weight are appreciated,* but with a sacrifice on account of the rather slight weight of the main-bulbs (e.g. 11 w. 26°); — or that *a fairly favourable number and weight of main-bulbs and secondary bulbs are preferably combined* (e.g. 3 w. 20° + 8 w. 17°).

It has become evident, that a different purpose set, requires a very different summer-treatment for the Tulip. But drawing a more exact conclusion and passing a judgment as to the application we would rather put off — apart from the above preliminary remarks —, till the data for part IV, as a control on a larger number of specimens, will be known to us in the summer of 1926, and likewise the results of the experiments on early flowering of this Darwin-Tulip.

LITERATURE CITED.

After the three parts hitherto issued on "The results of the temperature-treatment in summer for the Darwin-Tulip" (§§ 1—17; figures 1—5; tables 1—25), we refer to the following literature, connected with it, mentioned or further to be consulted.

1766. HILL, D. J. Die Art und Weise durch eine regelmässige Ordnung der Cultur oder Wartung, Gefüllte Blumen aus einfachen zu ziehen. Deutsche Uebers. a. d. Engl.

1886. GOEBEL, K. Beitr. z. Kenntnis gefüllter Blüthen. Jahrb. f. Wiss. Bot. Bd. 17. (Liliaceae S. 263).

In these the period of formation is already referred to and the rapid way in which this occurs in the Tulip, various illustrations of the formation being added.

1908. ORTLEPP, K. Der Einfluss des Bodens auf die Blütenfüllung der Tulpen. Flora Bd. 98.

1915. ORTLEPP, K. Monographie d. Füllungserscheinungen bei Tulpenblüten. Ausg. Th. Osw. Weigel. Leipzig.

For the sake of completeness we mention these works, all of them referring to full Tulip-flowers or the doubling of Tulips, while we again point out that the variation in the number of floral parts effected by the temperature in some Tulips, as Pride of Haarlem, is quite a different thing from the phenomenon of more or less full Tulips. The nature of the description in the above researches is quite different from what the temperature brought about in our observations, — since *all* whorls of floral parts in low temperatures increase to a (limited) number and each whorl mainly keeps its normal structure and function. Abnormal transitions are much less numerous than in "full" flowers. Besides summing up the types that occur (conclusion part II § 12) the best thing for us to do is to point out, that many of those abnormal formations are described in the above papers, especially in K. ORTLEPP's Monography (1915).

Further we referred to:

1920. A. H. BLAAUW, Over de Periodiciteit van Hyacinthus orientalis. With a summary in English. Meded. Landbouwhoogeschool Dl. XVIII, and Meded. No. 3. Labor. v. Plantenphys. Ond. Wageningen.

1922. A. H. BLAAUW. Klein Bouwwerk voor physiolog. Cultuurproeven. With a summary in English. Meded. Landbouwhoogeschool Dl. XXV. Meded. No. 7 Labor. v. Plantenphys. Ond. Wageningen.

1923. A. H. BLAAUW. De periodieke diktetoename van den bol der Hyacinthen. With a summary in English. Meded. Landbouwhoogeschool Dl. XXVII. Meded. No. 8 Labor. v. Plantenphys. Ond.. Wageningen.

1924. A. H. BLAAUW. The Results of the temperature during flower-formation for the whole Hyacinth. (First Part). Proc. Kon. Akad. v. Wet. Vol. XXIII. No. 4. Meded. No. 10 Labor. v. Plantenphys. Ond. Wageningen.

1924. A. H. BLAAUW. The results of the temperature during flower-formation for the whole Hyacinth. (Second part). Proc. Kon. Akad. v. Wet. Vol. XXVII. N^0. 9 and 10. Meded. No. 11 Labor. v. Plantenphys. Ond. Wageningen.

1926. R. MULDER. De periodieke ontwikkeling van de Darwin-Tulp. With a summary in English. Meded. No. 15 Labor. v. Plantenphys. Ond. Wageningen.

To this research already finished in outline, we had to refer in these papers.

1925. A. H. BLAAUW and Miss M. C. VERSLUYS. The results of the temperature-treatment in summer for the Darwin-Tulip. First part (§§ 1—7). Proc. Kon. Akad. v. Wet. Vol. XXVIII. No. 8 and 9. Meded. No. 17. Labor. v. Plantenphys. Ond. Wageningen.

1925. Miss I. LUYTEN, Miss G. JOUSTRA and A. H. BLAAUW, Idem. Second Part. (§§ 8—12). Proc. Kon. Akad. v. Wet. Vol. XXIX. Med. No. 18. Labor. v. Plantenphys. Ond. Wageningen.

Wageningen, November 1925.

Physics. — *"Influence of elastic deformation on the magnetic disturbance of the supraconductivity with tin. Hysteresisphenomena".* By G. J. SIZOO, W. J. DE HAAS and H. KAMERLINGH ONNES. (Comm. No. 180c from the Physical Laboratory at Leiden).

(Communicated at the meeting of November 28, 1925).

§ 1. *Introduction.*

As we stated in a preceding communication [1]) it has been found possible, by means of elastic deformation, to cause a small displacement of the temperature at which a metal becomes supraconductive.

The obvious course now was to investigate if the value of the magnetic field, at which a metal in the supraconductive state loses its supraconductivity, also might be influenced in this way. Namely, if we have a metal in the supraconductive state — that is in a state, in which the potential difference at the ends of a wire, through which an electric current is passing, has fallen below the limit of measurement — then as is known, it is possible to disturb this state by applying an external magnetic field — that is to bring back a measurable potential difference at the ends of the wire. Though the expression "threshold value of the magnetic field" which is still in use, suggests a discontinuous disturbance of the supraconductivity, in reality it was always found possible to follow the return of the potential difference in the magnetic field in such a way that the transition between the normal conductive and supraconductive state might be represented by a continuous transition curve [2]). To this curve we will give the name "magnetic transition curve". [3])

The state of the metal corresponding to this transition curve might be called the magnetic transitionphase.

The purpose of the inquiry was thus to find whether the magnetic transition curve might be displaced by means of elastic deformation of the wire. However, during the first measurements carried out with this purpose, besides the expected displacement a quite new phenomenon was discovered, which gave an unexpected turn to the inquiry.

Namely it appeared that the magnetic transition curve in reality is a hysteresisfigure.

By first enlarging the magnetic field, an "ascending" transition curve

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[1]) These Proceedings 28 (1925) p. 656.

[2]) Cf. Diss. W. TUYN. Leiden 1924, Cap. II.

[3]) In analogy with this, the curve which represents the appearing of the supraconductivity by lowering the temperature, without a magnetic field, might be called the „thermal transition curve". In the preceding communication the name „vanishing-curve" was introduced in connection with the use of the word „vanishing point".

was obtained, then by decreasing the field a "descending" one. These two together now formed a hysteresisfigure of a very peculiar form. This peculiar form, as well as the unexpectedness of the whole phenomenon caused us to accept the result with considerable reserve. Therefore a second "heliumday" was spent to determine the hysteresisfigure of two resistances with greater accuracy and under normal pressure.

The results of these two "heliumdays" are contained in this communication.

It is noteworthy that in the transition region between supra- and normal conductivity OHM's law fails. However, for the sake of simplicity we wish to retain in that region the term "resistance", by which is to be understood the quotient of the measured potential difference with the strength of the current through the wire.

§ 2. *Method of the experiment.*

The elastic deformation of the wire, mentioned above consisted in a compression by means of hydrostatic pressure. For the method of production of this pressure reference may be made to the preceding communication, as well as for the method of the resistance measurements etc. [1])

The magnetic field necessary was obtained with the inductance-coil *W*, mentioned in the dissertation of W. TUYN, page 69. The length of the coil is 18,9 cm., the diameter 13.6—16,4 cm., total number of turns 8×86 in 8 layers. The magnetic field obtained with this coil is not homogeneous.

Representing by H_z the strenght of the field at a point on the axis, at a distance z from one of the ends, and calling the lenght of the coil l, we have:

$$H_z = 4\pi\, ni \frac{1}{2} \left\{ \frac{z}{\sqrt{R^2 + z^2}} - \frac{z-l}{\sqrt{R^2 + (z-l)^2}} \right\} = 4\pi\, ni\, A_z .$$

Representing the maximum and minimum value of A — by $A_{max.}$ and $A_{min.}$, then the quotient $\frac{A_{min.}}{A_{max.}}$ is a measure of the inhomogeneity of the field. As the resistance was always placed in the axis of the coil and symmetrical to the middle of the coil the values $A_{max.}$ and $A_{min.}$ are found in the middle and at the ends of the resistance, respectively. With the aid of the given formula it is easy to calculate a mean value of A along the part of the axis, in which the resistance is placed.

The resistances used were *Sn*—1924—*A* and *Sn*—1925—*B*. Both were made of extruded tinwire, [2]) diameter 0,24 mm. They were wound on glass tubes with lengths of 9 and 6 cm., and diameters of 4 and 7 mm., respectively. The resistances at roomtemperature amounted to 2.17 and 4.55 Ω respectively.

In the case of the measurements with the resistance *Sn*—1924—*A* the

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[1]) L.c. pag. 659, § 4.

[2]) In the preceding communication (l.c. p. 656) it was stated that the wire was „drawn out". This is an error of translation.

values of A were: $A_{max.} = 0.783$, $A_{min.} = 0.730$, $A_{avg.} = 0.760$. The factor for the inhomogeneity was thus 0.932. The average fieldstrengths are calculated from the measured current strength with the formula:

$$H_{avg.} \text{ (in gauss)} - 4\,\pi\,n\,i\,A_{avg.} = 34.86\,i \text{ (in ampères)}.$$

With the measurements concerning Sn—1925—B we had $A_{max.} = 0.783$; $A_{min.} = 0.756$; $\frac{A_{min.}}{A_{max.}} = 0.965$; $A_{avg.} = 0.777$ and $H_{avg.}$ (in gauss) $= 35.64\,i$ (i in ampères).

§ 3. *The measurements of* 16 *Jan.* 1925.

These measurements contain determinations of the magnetic transition-curves for the wire Sn—1924—A under pressures of 4, 100, and 250 kg./cm.^{2}, respectively, at a temperature of 3.414°—3.416° K. The results are contained in Table I. Besides the values of the resistances (third column: W_{sn}—1924—A) the ratios of these values to the resistance at 4.20° K. are given $\left(\text{fourth column: } \frac{W}{W_{4.2}}\right)$. This amounted to 0.00132 Ω.

In the figures, for the sake of uniformity, these quotients, indicated by $\frac{W}{W_{4.2}}$, are plotted. In fig. 1, as an example, the results obtained with a

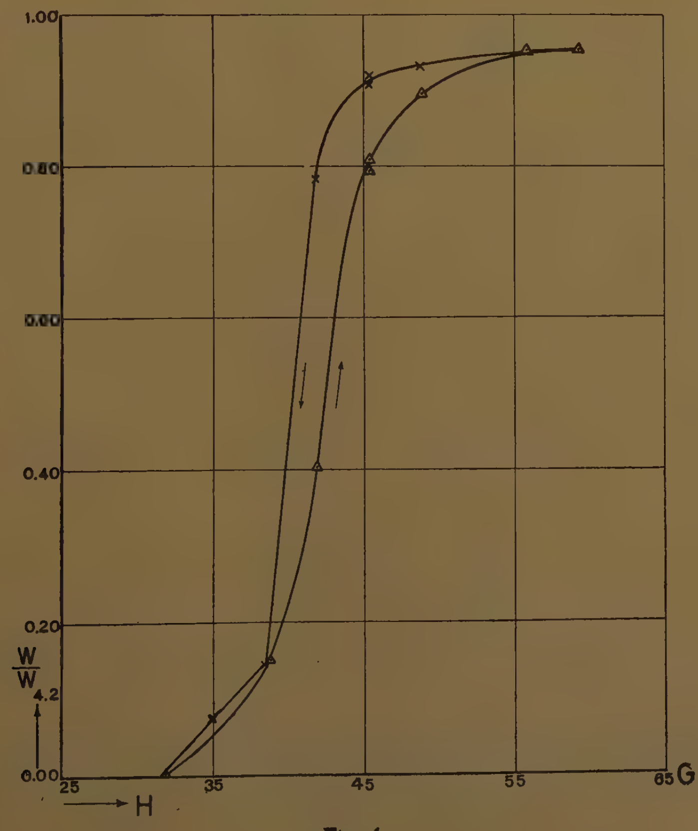

Fig. 1.

TABLE I. Measurements of 16 January 1925.

Pressure in kg/cm²	$H_{avg.}$ in gauss	$W_{Sn-1924-A}$	$\frac{W}{W_{4.2}}$
4	48.80	0.00112 Ω	0.849
	52.29	0.00116	0.879
	55.78	0.00118	0.894
	62.75	0.00122	0.925
	69.72	0.00123	0.932
	45.32	0.00114	0.864
	41.83	0.00042	0.318
	38.35	0.00023	0.174
	34.86	0.00012	0.091
	31.37	0.00000	0.000
	0	0.00000	0.000
	31.37	0.00000	0.000
	34.86	0.00008	0.061
	38.35	0.00018	0.136
	41.83	0.00037	0.280
	45.32	0.00093	0.705
	48.80	0.00111	0.841
	52.29	0.00117	0.887
100	34.86	0.00008	0.061
	38.35	0.00023	0.174
	41.83	0.00048	0.364
	45.32	0.00101	0.766
	48.80	0.00113	0.857
	52.29	0.00118	0.894
	59.26	0.00122	0.925
	48.80	0.00117	0.887
	45.32	0.00112	0.849
	41.83	0.00090	0.682
	38.35	0.00019	0.144
	34.86	0.00012	0.091
250	31.58	0.00001	0.009
	38.35	0.00022	0.167
	41.83	0.00053	0.402
	45.32	0.00106	0.803
	48.80	0.00118	0.894
	55.78	0.00126	0.955
	48.80	0.00123	0.932
	45.32	0.00120	0.909
	41.83	0.00103	0.781
	38.35	0.00019	0.144
	34.86	0.00010	0.076
	45.32	0.00105	0.795
	59.26	0.00126	0.955
	45.32	0.00120	0.910

pressure of 250 kg./cm.^{2} are given. *The hysteresis, already mentioned, becomes clearly evident.* The peculiar form of the "descending-curve" is very obvious. The figures, obtained with 4 and 100 kg./cm.^{2} show quite the same nature. In fig. 2 the three ascending curves are combined. The descending ones are omitted because the number of points with which

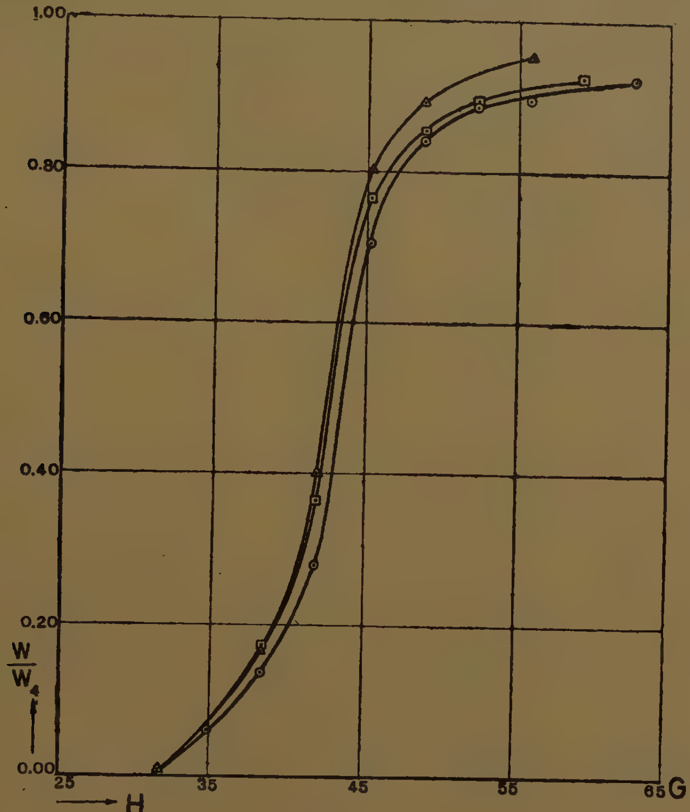

Fig. 2.
⊙ 4 kg/cm^2 hydrostatic pressure.
⊡ 100 " " "
△ 250 " " "

these were determined was too small to be sure about the mutual situation of these curves.

From fig. 2 it is clear how the ascending curve is shifted by the application of the pressure to the side of the lower fields.

On the place where the resistance has half disappeared, this displacement amounts to about 0.8 gauss for 100 kg/cm^2.

If it may be assumed that the application of the pressure causes a decrease of the distances between the atoms, then the result found may be expressed thus: *"for the disturbing of the supraconductivity by a magnetic field, a relatively small space between the atoms is favourable".*

It is noteworthy that the displacement of the curve with increasing pressure, at least in the middle of the transition region soon seems to have

reached a maximum value. As appears from the preceding communication, the same was the case with the displacement of the thermal transition curve.

§ 4. *The measurements of* 30 *Jan.* 1925.

It is understandable that after the results, mentioned in the preceding paragraph, the necessity was felt to confirm the found hysteresis. Especially the peculiar form of the descending curve made us hesitate to accept the reality of the phenomenon. It was thus considered desirable to determine the hysteresisfigure with more than one resistance and with greater

TABLE II. Measurements of 30 January 1925.

Current	$H_{avg.}$ in gauss	$W_{Sn-1924-A}$	$\frac{W}{W_{4.2}}$
2.0 mA	31.37	0.00000 Ω	0.066
	34.86	0.00008	0.056
	38.35	0.00015	0.113
	41.83	0.00043	0.324
	43.92	0.00080	0.602
	45.32	0.00095	0.714
	48.80	0.00110	0.827
	52.29	0.00115	0.865
	55.78	0.00118	0.887
	59.26	0.00120	0.902
	55.78	0.00120	0.902
	52.29	0.00118	0.887
	48.80	0.00113	0.850
	45.32	0.00105	0.790
	42.53	0.00090	0.677
	41.83	0.00088	0.662
	41.13	0.00078	0.587
	40.44	0.00063	0.474
	39.74	0.00048	0.361
	38.35	0 00015	0.113
	34.86	0.00008	0.056
	31.37	0.00000	0.000

TABLE III. Measurements of 30 January 1925.

Current	$H_{avg.}$ in gauss	$W_{Sn-1924-A}$	$\frac{W}{W_{4.2}}$
4.0 mA	31.37	0.00000 Ω	0.000
	34.86	0.00006	0.045
	36.60	0.00010	0.075
	37.65	0.00013	0.098
	38.35	0.00015	0.113
	40.09	0.00021	0.158
	41.83	0.00033	0.248
	43.58	0.00060	0.451
	44.62	0.00073	0.549
	45.32	0.00086	0.647
	46.36	0.00091	0.648
	47.06	0.00097	0.729
	47.93	0.00101	0.760
	48.80	0.00107	0.805
	50.55	0.00112	0.842
	52.29	0.00115	0.865
	55.78	0.00118	0.887
	59.26	0.00121	0.910
	57.80	0.00121	0.910
	55.78	0.00121	0.910
	53.61	0.00120	0.902
	52.15	0.00118	0.887
	50.76	0.00115	0.865
	48.80	0.00115	0.865
	47.41	0.00111	0.835
	45.39	0.00102	0.767
	44.62	0.00100	0.752
	43.92	0.00100	0.752
	43.23	0.00091	0.684
	42.53	0.00084	0.632
	41.73	0.00069	0.519
	40.33	0.00042	0.316
	39.74	0.00018	0.135
	39.04	0.00016	0.120
	38.35	0.00014	0.105
	37.65	0.00014	0.105
	36.95	0.00011	0.083
	36.25	0.00010	0.075
	35.56	0.00009	0.068
	31.37	0.00003	0.019

TABLE IV. Measurements of 30 January 1925.

Current	$H_{avg.}$ in gauss	$W_{Sn-1924-A}$	$\frac{W}{W_{4.2}}$
6.7 mA	31.37	0.00002 Ω	0.011
	34.86	0.00008	0.060
	38.35	0.00018	0.135
	39.74	0.00023	0.173
	41.83	0.00040	0.301
	43.92	0.00071	0.534
	45.32	0.00085	0.639
	46.71	0.00098	0.737
	48.80	0.00108	0.812
	50.90	0.00113	0.150
	52.29	0.00116	0.872
	55.78	0.00122	0.917
	59.26	0.00123	0.925
	55.78	0.00123	0.925
	52.29	0.00120	0.902
	50.90	0.00119	0.895
	48.80	0.00116	0.872
	46.64	0.00110	0.827
	45.32	0.00107	0.805
	44.27	0.00104	0.782
	43.44	0.00098	0.737
	42.53	0.00092	0.692
	41.83	0.00081	0.609
	41.00	0.00059	0.444
	39.74	0.00024	0.180
	39.04	0.00023	0.173
	38.35	0.00018	0.135
	37.65	0.00017	0.128
	36.95	0.00015	0.113
	36.25	0.00014	0.105
	35.56	0.00011	0.083
	34.86	0.00011	0.083
	34.16	0.00009	0.068
	33.46	0.00007	0.053
	32.77	0.00006	0.045
	31.37	0.00004	0.030
	29.98	0.00001	0.008
	27.89	0.00000	0.000

TABLE V. Measurements of 30 January 1925.

Current	$H_{avg.}$ in gauss	$W_{Sn—1925—B}$	$\frac{W}{W_{4.2}}$
2.0 mA	39.20	0.00062 Ω	0.104
	42.77	0.00137	0.222
	46.33	0.00509	0.825
	49.90	0.00609	0.987
	53.46	0.00615	0.996
	60.59	0.00615	0.996
	46.33	0.00614	0.995
	42.77	0.00464	0.752
	40.63	0.00063	0.102
	39.92	0.00054	0.088
	39.20	0.00050	0.081
	37.07	0.00037	0.060
	35.64	0.00029	0.047
	32.08	0.00016	0.026
	28.51	0.00000	0.000
	32.08	0.00003	0.005

accuracy under normal pressure. This was done 30 Jan. 1925 with the resistances *Sn*—1924—*A* and *Sn*—1925—*B*. The first was again placed within the copper cylinder of the pressure-apparatus, the latter was fixed to it on the outside. The resistances at 4°.20 K amounted to 0.00132 Ω and 0.00617 Ω. At a temperature of 3.414°—3.416° K. the form of the hysteresisfigure was determined for *Sn*—1924—*A* with currents of 2,4 and 6.7 mA resp. and for *Sn*—1925—*B* with a current of 2 mA.

The results are given in the Tables II, III, IV, and V. All points are given in the order in which they were measured. The results are in good agreement with those of the preceding measurements. In the figures 3 and 4 the hysteresisfigures of *Sn*—1924—*A* measured with 6.7 and 4.0 mA resp. are given as an example.

In both figures, but especially in the latter the position of the measured points on the descending line raised the suspicion that this curve was not continuous (see the dotted line in fig. 4). Moreover this impression had already been gained during the measurements. No decision as to the correctness of this suggestion has yet been obtained, as no further measurements with extruded and wound tinwires have been made. The results

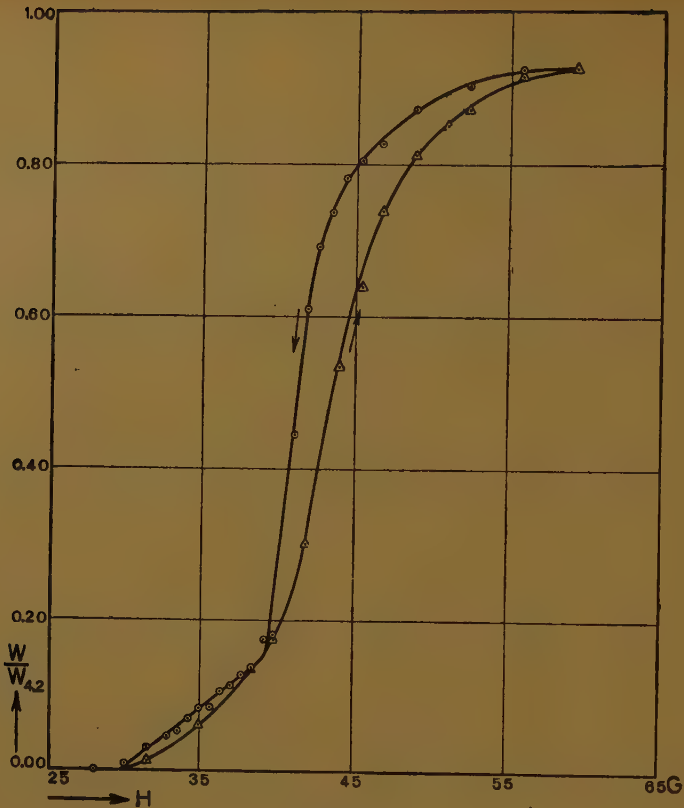
1.00
0.80
0.60
0.40
0.20
0.00
W/W4.2
25
35
45
55
65G
H

Fig. 3.

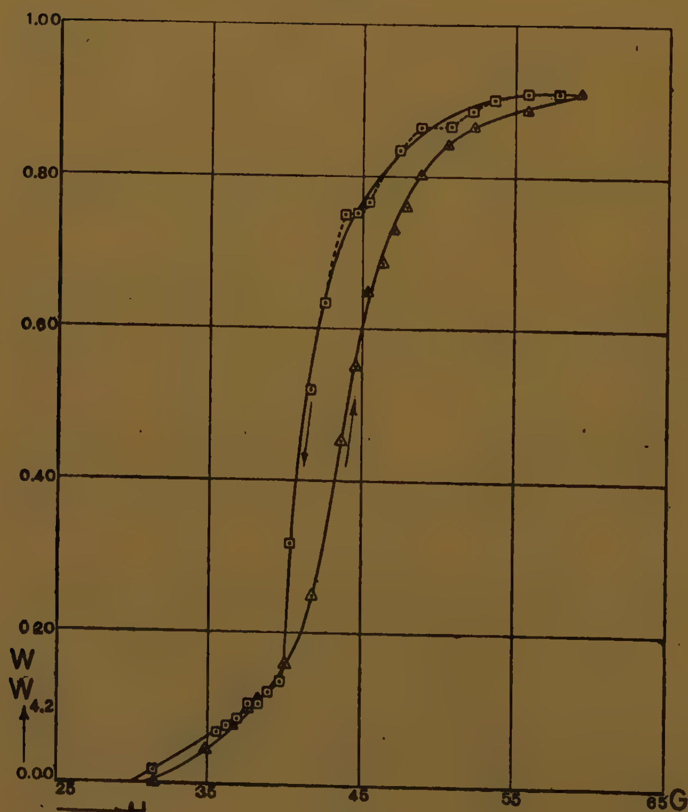
1.00
0.80
0.60
0.40
0.20
0.00
W/W4.2
25
35
45
55
65G
H

Fig. 4.

afterwards found with mercury, however, give a strong support to this suggestion.

The measurements with different currents were carried out to obtain evidence as to the influence of the current strength on the form of the transition line, which influence is discussed on page 89 of the dissertation of W. TUYN.

In fig. 5 are represented the three ascending lines. obtained with 2.0, 4.0 and 7.6 mA. A regular displacement is not evident. Thus here also the question of the influence of the current remains as yet unanswered.

In connection with the complicated circumstances this is not to be

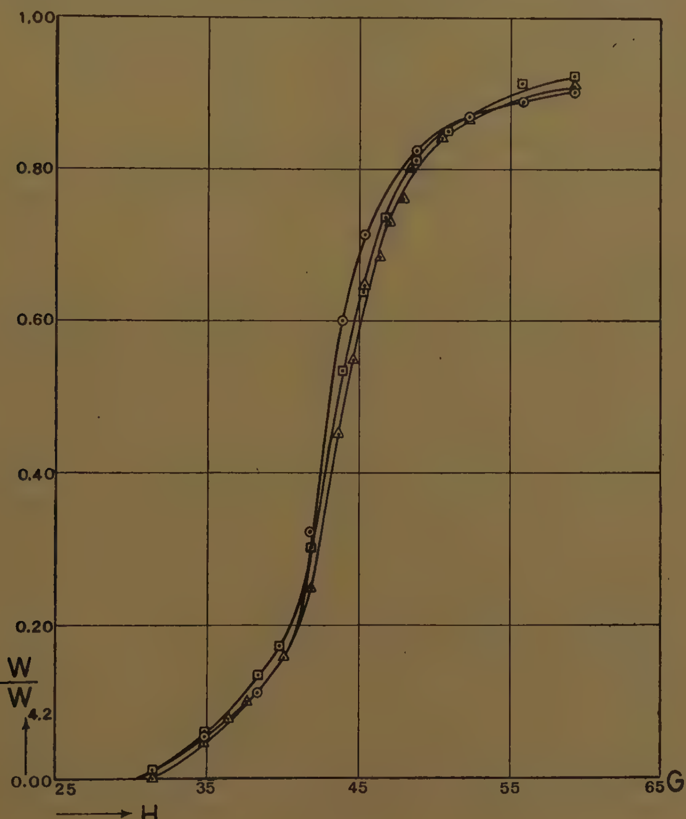

Fig. 5.

⊙ measuring current 2 mA.
△ „ „ 4 mA.
⊡ „ „ 6.7 mA.

wondered at. It is to be remembered that the field was neither homogeneous nor, because the wire was wound, quite transversal.

To get further information about the nature of the hysteresis, the following control-experiments were made:

a). The magnetic field is raised until the resistance of the wire has partly returned; (example: $W_{Sn-1924-A} = 0.00042\ \Omega$ for $H = 42.53$ gauss).

The field is now enlarged till the resistance has come back almost completely, (example: $W_{Sn-1924-A} = 0.00122\ \Omega$ for $H = 60$ gauss), then diminished to the original value and the resistance measured again, (example: $W_{Sn-1924-A} = 0.00082\ \Omega$ for $H = 42.53$ gauss). The last point is thus situated on the descending curve.

b. To see if there is an influence of the time we now waited about 20 minutes. The resistance remains unchanged.

c. The current through the magnetic coil is now broken and immediately afterwards closed again. The resistance is measured again and appears to be situated on the ascending curve (example: $W_{Sn-1924-A} = 0.00042\ \Omega$).

d. The manipulations, mentioned under *a*, are performed again. Then the magnetic field is left unchanged but the temperature is raised to a value higher than the vanishing-point of tin and afterwards decreased to exactly the same value. Now the resistance is found to be on the descending curve (example: $W_{Sn-1924-A} = 0.00082\ \Omega$).

All these experiments were repeated some times with *Sn*—1924—*A* as well as with *Sn*—1925—*B* and always with the same results.

§ 5. *Discussion.*

After the results, mentioned in the preceding paragraphs, were obtained there could be no doubt as to the existence of the hysteresis. Still there might have been a very small possibility that the hysteresis might not be a property of the supraconductivity but a consequence of an impurity of the tin, namely the presence of iron. In that case the remanent magnetism of the iron would be responsible for the hysteresis. Though the experiment, mentioned under *c*, was against this suggestion, it was considered as desirable to investigate the phenomenon with a supraconductor with which contamination with iron was surely excluded. Besides it was desirable to repeat the measurements under less complicated circumstances, namely in a much more homogeneous field, oriented exactly parallel or perpendicular to the direction of the current. It was resolved to investigate the phenomenon with mercury, which may easily be obtained in a state of great purity by repeated distillation and with which, by enclosing in glasscapillaries at small length a sufficient high value of the resistance may be obtained.

The results of these inquiries, as far as they have progressed now, are to be given in a following communication.

Physics. — "*On the magnetic disturbance of the supraconductivity with mercury*". I. By W. J. DE HAAS, G. J. SIZOO and H. KAMERLINGH ONNES. (Comm. N°. 180*d* from the Physical Laboratory at Leiden).

(Communicated at the meeting of November 28, 1925).

§ 1. *Purpose and method of the experiments.*

As was mentioned in § 5 of the preceding communication [1]), the purpose of the investigation which is to be recorded here, was to find out if the magnetic disturbance of the supraconductivity with mercury shows a similar hysteresis, as was observed with tin. In that case, there would be no doubt that this hysteresis had to be considered as a property of the supraconductivity and not as due to a contamination with iron.

The result of the investigation was not only that the hysteresis really exists, but besides that the graphs of the magnetic disturbance show very sharp discontinuities.

Fig. 1.

The measurements were carried out with mercury threads, enclosed in glasscapillaries which were provided with four platinum wires.

In the beginning of the investigation the resistances had the form shown in figure 1, later that in figure 2. The latter had the advantage over the former, that the resistances required less room in the cryostat and besides, that the quantity of mercury, which had to be displaced through the capillary during the cooling was smaller, so that the chance of breaking of the mercury thread was decreased. We will distinguish the two types as type I and type II respectively. Always as many resistances were placed in the cryostat as the available space allowed. Even with very careful cooling the mercury threads of about half the number of the resistances generally broke. Besides, when after the measurements, the resistances were heated again from heliumtemperatures to roomtemperature, some on the glasscapillaries usually broke. Because of this we have not yet succeeded in measuring one resistance on two different heliumdays.

Fig. 2.

To apply the field one of the two inductance coils W and A was used. The first is the same as mentioned in the preceding communication [2]) and was placed round the cryostat.

[1]) G. J. SIZOO, W. J. DE HAAS and A. KAMERLINGH ONNES. These Proceedings **29** (1926) p. 221.

[2]) L. c. p. 222.

The second was placed *in* the cryostat. Its length amounted to 16.5 cm., internal diameter 2.10 cm., number of turns 1500. In the beginning of the investigation the length of the resistances was rather great — e. g. 8 cm. Afterwards much smaller ones were used (10—15 mm.) For these latter the field obtained with coil *A* may be considered as practically homogeneous.

Only once we measured with a transverse field, obtained by means of an electromagnet with broad polepieces, between which the outer glass of the cryostat just fitted.

The resistances were measured again with the compensation apparatus. For the way in which the temperatures were determined we may refer to a preceding communication [1]).

For the sake of sharp and quick observing of the discontinuous changes in the resistances the cooperation of two observers appeared desirable.

While by the first one the current through the coil was changed by means of variable resistances as slowly and continuously as possible, the galvanometer was observed by the second. The appearance of a jump in the resistance was shown by a sudden deflection of the galvanometer, which by compensation had first been brought back to its nullpoint.

As soon as this happened the field was kept constant and the new value of the resistance measured.

By repetition the situation of a jump could be usually determined to some tenths of a gauss (0.1 to 0.2 scale division of the reading on the Weston-ampèremeter, with which the current was measured [2])).

§ 2. *The measurements.*

As there were no data on the magnetic disturbance of the supraconductivity with mercury, our first measurements had to be of an orienting nature.

We will record the course of the research in chronological order:

1. *Measurements of 18 March 1925.*

Used resistance *Hg*—1925—*A*. Model 1, length of the capillary 11.5 cm., diameter 0.095 mm. Field obtained with coil *W*. Owing to lack of time the existance of the hysteresis could be only qualitatively ascertained.

2. *Measurements of 30 April 1925.*

Used resistance *Hg*—1925—*C*, model 1, length of the capillary 83 mm.,

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1) These Proceedings **27** (1925) p. 656.

2) Of course the question arose during the investigation and especially in the beginning as to whether the cause of the discontinuities did not lie in the apparatus. We therefore took all precautions to exclude this possibility (e.g. replacement of the SIEMENS and HALSKE galvanometer by a ZERNIKE galvanometer with a sensibility three times as high, and a time of leg of only three seconds; the use of carbon rheostats, which might be varied in a very continuous way; the use of various calibrated milli-ampèremeters; of various leads etc.).

diameter 0.2 mm. Resistance at roomtemperature 2.648 Ω. Field obtained with coil W. Data for the inhomogeneity of the field. [1])

$$A_{max} = 0.783\,; \qquad A_{min} = 0.699\,; \qquad \frac{A_{min}}{A_{max}} = 0.893;$$

$$A_{avg} = 0.765\,; \qquad H_{avg}\ \text{(in gauss)} = 35.09\, i \ \ (i \text{ in ampères}).$$

The results of the measurement, carried out 4°.036 K are contained in table 1. The number of points is too small to show the form of the hysteresisfigure with certainty. The "descending line" shows a horizontal part, which raised the suspicion of discontinuity.

3. *Measurements of 15 May 1925.*

Resistance *Hg—1925—E*, model 1, length 83 mm., diameter 0.2 mm. The hysteresisfigure was determined at a temperature of 3°.796 K., with a *longitudinal* field (coil W) as well as with a *transverse* field (electromagnet). *In both cases in the descending curves discontinuities were observed.* (See tables II and III).

For the longitudinal field we had:

$$A_{max} = 0.783; \qquad A_{min} = 0.699; \qquad \frac{A_{max}}{A_{min}} = 0.893;$$

$$A_{avg} = 0.765; \qquad H_{avg} = 35.09\, i.$$

The inhomogeneity of the transversal field was not determined. The mean point for us was to know whether or not there existed an essential difference between the behaviour of the resistance in a longitudinal and a transverse field. This appeared not to be the case. Although not all jumbs in the descending curves were determined with certainty, still it is sure, that neither their number nor their situation were the same in both cases. The ascending lines are not observed with sufficient accuracy to decide the presence or absence of discontinuities. A remarkable result of this measurement was further that the maximum value of the resistance, which could be brought back by the magnetic field, amounts only to 70 % of the resistance at 4°.20 K., just above the "vanishing-point". In the tables are given, besides the values of the resistances, the ratios of these values to the value of the resistance at 4°.20 K. These quotients are called $\frac{W}{W_{4.2}}$. The maximum value of this quotient amounts to 0.70 for the longitudinal and 0.706 for the transverse field. This partial return of the resistance, confirmed by all further measurements, was later especially investigated. [2])

4. *Measurements of 26 May 1925.*

Used resistance *Hg-1925-G*, model I, length 24 mm., diameter 0.052 mm. Resistance at roomtemperature 8.20 Ω; at 4°20 K. 0.00378 Ω.

The length of the resistance was made short to get a higher homo-

[1]) See preceding communication. These Proceedings **29** (1926) p. 222.

[2]) See measurements of 22 Nov. 1925, mentioned in second part of this communication.

geneity of the field over the length of the resistance. With this measurement the jumps were observed for the first time on the method, mentioned in § 1. The field was obtained with coil W.

In the ascending as well as in the descending line discontinuities were observed.

The tables IV and V contain the results of the measurements, carried out at temperatures of 3°.796 and 3°.962 K. with currents of 4 and 2 mA. respectively. For these measurements the resistance was placed, as usual in the middle of the coil. The values of A were

$$A_{max} = 0.783; \quad A_{min} = 0.778; \quad \frac{A_{min}}{A_{max}} = 0.994;$$
$$A_{avg} = 0.781; \quad H_{avg} = 35.82\ i.$$

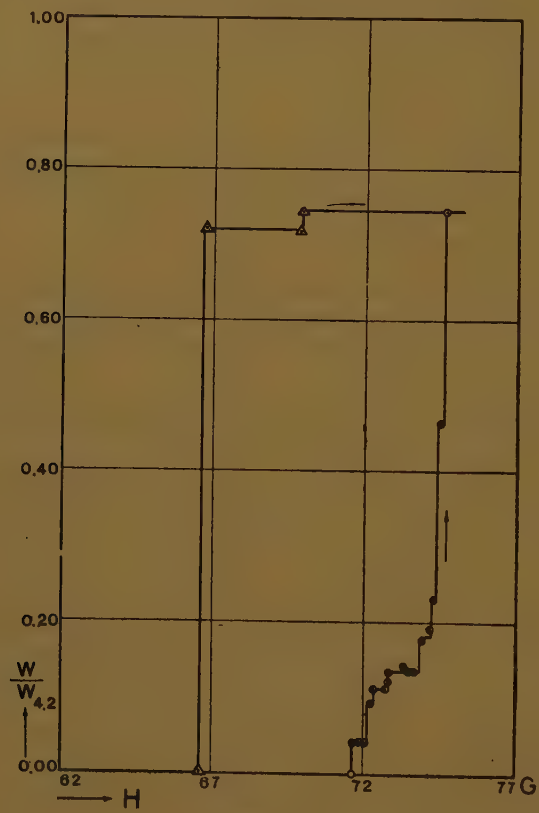

Fig. 3.

To detect the influence of the inhomogeneity of the field, the coil was displaced about 6 cm. in reference to the resistance, so that this now situated in a much less homogeneous field. The data of the inhomogeneity now were:

$$A_{max} = 0.705; \quad A_{min} = 0.596; \quad \frac{A_{min}}{A_{max}} = 0.845;$$
$$A_{gem} = 0.657; \quad H_{gem} = 30.13\ i.$$

The results, stated in table VI were thus obtained. The temperature again amounted to 3°.962 K, the measuring current was 2 mA.

The data from table IV are represented in fig. 3, those from table V and VI in fig. 4.

From fig. 4 it is clear that the influence of the inhomogeneity of the field is felt principally in the increase of the number of jumps in the ascending line [1]). The descending line retains its simple nature, which

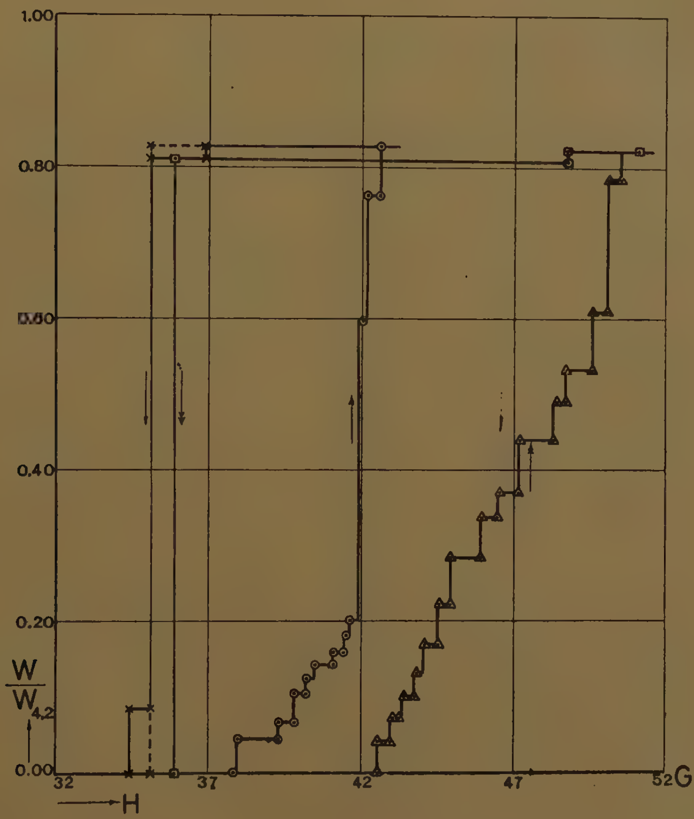

Fig. 4.

⊙ × } homogeneous field ▲ ⊡ } inhomogeneous field

seems to indicate *that the resistance of a part of the thread can only disappear when over its whole length the field strength has fallen below a certain value.* The dotted parts in both figures show that sometimes,

[1]) As the resistances are plotted against the *average* values of the field a displacement of the ascending line to the side of the lower fields would be expected rather than the displacement to the higher fields, which is seen from the figure. The latter may be due to an error in the measurement of the displacement of the coil (perhaps this amounted to 7 cm. instead of 6 cm.). Because of this uncertainty we did not try to compare the both figures from a quantitative point of view. *(Note added in the translation).*

through some unknown cause, a jump may be omitted. Here as well as in later measurements it was endeavoured to detect the cause of this phenomenon, but without success. For example it has been ascertained that the speed with which the magnetic field is changed, has no influence. It is seen that the value $\left\{\frac{W}{W_{4.2}}\right\}_{max}$ at higher temperatures is larger than at lower [1]) and that the breadth of the hysteresisfigure is largest at the lowest temperature.

5. *Measurements of 5 June* 1925.

Of the resistances, placed within the cryostat, only *Hg*—1925—*D* was not broken. This was still of type I, length 83 mm., diameter 0.18 mm. At roomtemperature the resistance was 3.128 Ω, at 4°.20 K 0.00140 Ω. Field obtained with coil *W*. The dates for the inhomogeneity of the field are the same as with the measurements of 15 May 1925. With this resistance a number of experiments were carried out to get more information as to the nature of the discontinuities (only the descending line was measured, table VII). The following results were obtained.

a. The jumps are simple and not composed from a number of discontinuities following each other rapidly.

b. The number and the situation of the jumps does not depend on the current through the resistance. Example:

$i = 8$ mA, jump at 63,1 reading of the Weston Ampèremeter.
$i = 0.4$ mA, „ at „ „ „ „ „ „

c. When it is desired to reproduce the descending line or a part of it, then it appears necessary to first increase the field so far that the resistance is brought back as far as possible. If this is not done, but only a smaller part of the resistance is brought back, then by decreasing the field, quite other discontinuities appear as in the first case.

6. *Measurements of 12 June* 1925.

The results of the measurements of 26 May 1925 had raised the suggestion that with still higher homogeneity of the field, the hysteresisfigure would attain a very simple nature. To test this suggestion two resistances of small length, made according to type II, were placed in coil A, within the cryostat [2]), namely, *Hg*—1925—*K* and *Hg*—1925—*L*, with lengths of 18 and 20 mm. and diameters of 0.045 and 0.023 mm. respectively. The resistances at roomtemperature amounted to 8.22 Ω and 35.14 Ω, and at 4°20 K to 0.00482 Ω and 0.0204 Ω respectively. The inhomogeneity of the field over the length of these resistances was pro-

[1]) See the measurements of 22 Nov. 1925.

[2]) The same had already been done with the measurements of 5 June. That time howether both resistances were broken during the cooling!

bably too small to have any influence: $A_{max} = A_{min} = A_{avg} = 0.992$. $H = 113.3i$. At 3°.790—3°.793 K, for both resistances the hysteresisfigures were determined: table VIII (*Hg*—1925—*L*); table IX (*Hg*—1925—*K*) and figure 5. The figure shows, how, notwithstanding the homogeneity of the field, the hysteresisfigures are not so simple as was expected.

The ascending lines in both cases are continuous again. As the galvanometer was observed continuously during the gradually increasing of the field, the absence of discontinuities is more certain than is indicated

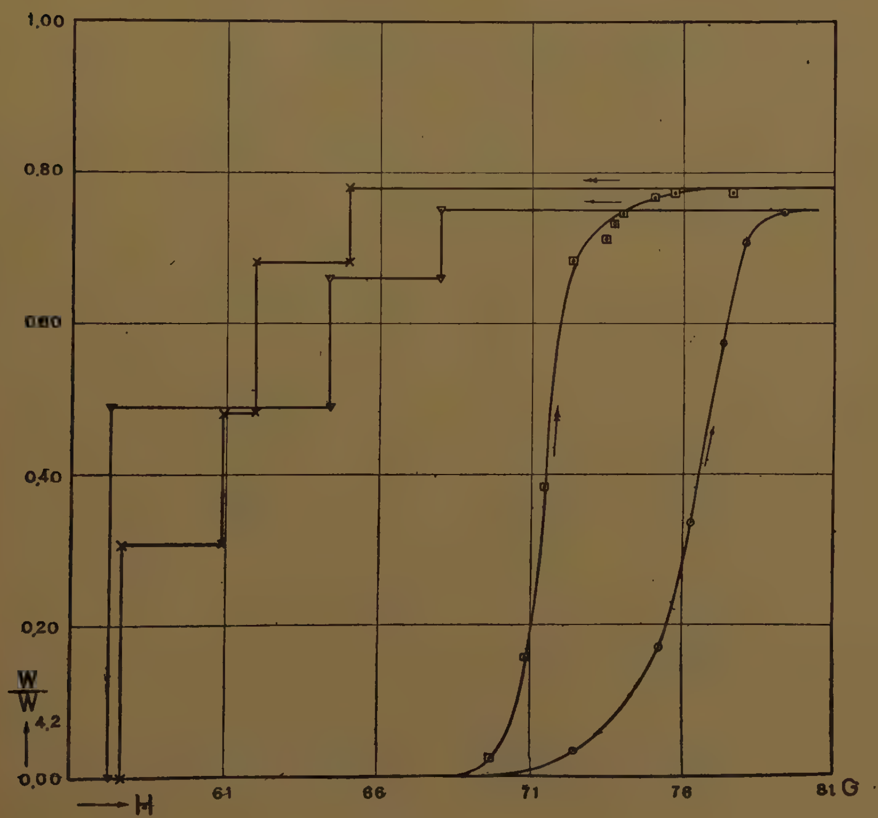

Fig 5.

⊙ ▽ } *Hg—1925—L* ⊡ × } *Hg—1925—K*

by the few number of measured points. The descending curves show 4 and 3 jumps respectively and the breadth of the figure is particularly great. The unexpectedness of these results gave us cause to suppose, that perhaps *local inhomogeneities* in the magnetic field would cause the discontinuities. To test this possibility it was resolved to measure a hysteresisfigure with coil *A* as well as with coil *W*. This was carried out during the:

7. *Measurements of* 3 *July* 1925.

Resistance *Hg*—1925—*P*, length 10 mm., diameter 0.04 mm., type II, placed within coil *W*.

a. At a temperature of 3°.963 K the hysteresisfigure is measured, first with coil *A*, afterwards with coil *W*. (Tables X and XI).

No essential difference between both figures was found. (see fig. 6). The ascending lines in both cases show no discontinuities, in the descending lines, there appear sometimes two, sometimes three. With the measurement with coil *A* two of the jumps followed each other so closely

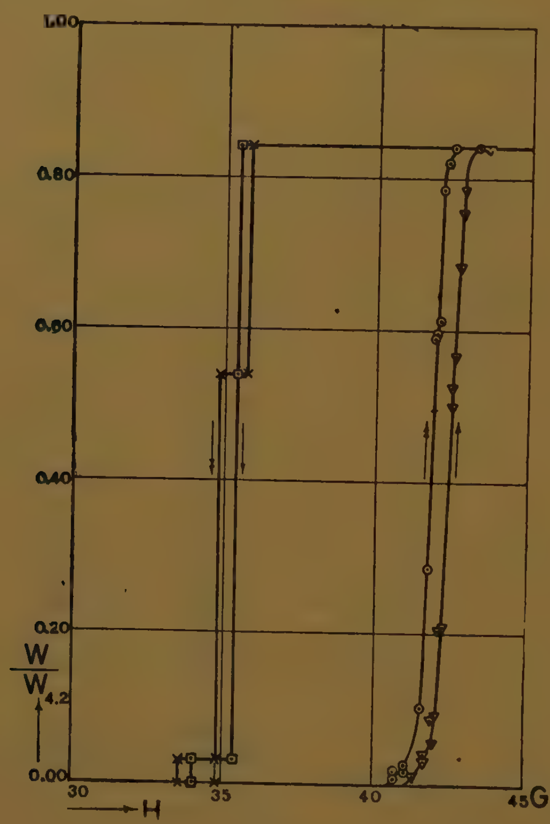

Fig. 6.

▽ □ } Coil *A* ⊙ × } Coil *W*

that it was difficult to separate them. When this is considered as a passing of the first jump, then the two figures are quite similar. They are only shifted relative to one another over a distance of about 0.5 gauss, which is quite admissable because in the factor *C* from the formula $H = Ci$ an uncertainty of about 1 % exists.

b. The situation of the jumps here also appeared independent of the current, even when this was varied between 28 and 1 mA.

TABLE I. Measurements of 30 April 1925.

$H_{avg.}$ [1] (in gauss)	$W_{Hg-1925-C}$	$H_{avg.}$ (in gauss)	$W_{Hg-1925-C}$
21.05	0.00000 Ω	22.67	0.00072 Ω
24.56	0.00040	21.79	0.00012
28.07	0.00107	21.05	0.00013
31.58	0.00111	20.35	0.00011
35.09	0.00113	19.65	0.00009
38.60	0.00114	18.95	0.00000
35.09	0.00112	19.65	0.00000
31.58	0.00112	20.42	0.00000
24.56	0.00112	21.05	0.00002

TABLE II. Measurements of 15 May 1925.

$H_{avg.}$ (in gauss) transversal	$W_{Hg-1925-E}$	$\frac{W}{W_{4.2}}$	Remarks
56.78	0.00000 Ω	0.00	
64.84	0.00011	0.10	
69.00	0.00025	0.24	
73.15	0.00058	0.55	
77.22	0.00068	0.65	
81.87	0.00075	0.71	
89.93	0.00079	0.75	
85.29	0.00075	0.71	
77.14	0.00076	0.72	
69.00	0.00074	0.70	
65.74	0.00074	0.70	jump
65.33	0.00061	0.58	
64.60	0.00061	0.58	
62.72	0.00055	0.52	
61.91	0.00055	0.52	
60.85	0.00055	0.52	
59.63	0.00055	0.52	"
58.41	0.00034	0.32	" ?
56.78	0.00025	0.24	"
54.99	0.00013	0.12	
53.76	0 00013	0.12	
52.13	0.00013	0.12	
48.63	0.00013	0.12	" ?
	0.00000	0.00	

[1]) When there is nothing mentioned to the contrary the magnetic field was longitudinal, i. e., parallel to the lenght of the mercury thread.

TABLE III. Measurements of 15 May 1925.

$H_{avg.}$ (in gauss)	$W_{Hg-1925-E}$	$\frac{W}{W_{4.2}}$	Remarks
70.80	0.00000 Ω	0.00	
71.50	0.00013	0.12	
72.20	0.00030	0.29	
72.82	0.00040	0.38	
74.21	0.00046	0.44	
74.91	0.00048	0.45	
76.51	0.00052	0.49	
77.77	0.00058	0.55	
79.85	0.00069	0.66	
82.01	0.00073	0.70	
83.40	0.00074	0.705	
86.96	0.00076	0.72	
90.50	0.00076	0.72	
88.35	0.00076	0.72	
86.26	0.00076	0.72	
85.49	0.00076	0.72	
83.40	0.00074	0.70	
82.01	0.00074	0.70	
79.85	0.00074	0.70	jump
78.81	0.00070	0.67	
78.11	0.00070	0.67	
77.28	0.00070	0.67	"
76.30	0.00062	0.59	
75.75	0.00060	0.57	
75.12	0.00059	0.56	"
74.21	0.00054	0.51	
73.59	0.00052	0.49	
72.54	0.00053	0.50	"
72.06	0.00040	0.38	
71.64	0.00042	0.40	
70.66	0.00036	0.34	"
70.11	0.00023	0.22	
69.41	0.00022	0.21	
68.71	0.00022	0.21	
67.46	0.00022	0.21	
66.97	0.00022	0.21	
66.63	0.00022	0.21	"
66.28	0.00000	0.00	

TABLE IV. Measurements of 26 May 1925.[1]

$H_{avg.}$ (in gauss)	$W_{Hg-1925-G}$	$\frac{W}{W_{4.2}}$	Remarks
71.56	0.00000 Ω	0.000	jump
71.70	0.00016	0.042	
↓			
72.16	0.00035	0.093	„
↓			
72.34	0.00042	0.112	„
↓			
72.77	0.00046	0.121	„
↓			
72.91	0.00049	0.131	„
↓			
73.34	0.00053	0.141	„
↓			
73.91	0.00068	0.179	„
↓			
74.19	0.00072	0.192	„
↓			
74.26	0.00089	0.236	„ ?
↓			
74.41	0.00175	0.463	„ ?
↓			
74.6	0.00282	0.746	„
94.6	0.00282	0.746	
↓			
69.8	0.00271	0.718	„
↓			
66.57	0.00000	0.000	„

[1]) The arrows in this and the following tables indicate that during the changing of the magnetic field the resistance remained first constant and then suddenly changed to a new value. Thus they correspond with the horizontal parts of the disturbance-lines.

Very often between two jumps it was controlled by special measurement that the resistance did not alter. These measurements have been omitted in the tables and figures. Where there was no certainty as to the presence of a jump, this has been queried in the tables.

TABLE V. Measurements of 26 May 1925.

$H_{avg.}$ (in gauss)	$W_{Hg-1925-G}$	$\frac{W}{W_{4.2}}$	Remarks
37.77	0.00000 Ω	0.000	jump
38.06	0.00017	0.045	
↓			
39.34	0.00025	0.065	,,
↓			
39.84	0.00039	0.104	,,
↓			
40.20	0.00047	0.123	,,
↓			
40.48	0.00054	0.142	,,
↓			
41.20	0.00059	0.155	,,
↓			
41.48	0.00069	0.181	,,
↓			
41.62	0.00076	0.201	,,
↓			
41.98	0.00225	0.596	,, ?
↓			
42.12	0.00288	0.762	,,
↓			
42.55	0.00313	0.828	,,
53.81	0.00313	0.828	
↓			
35.06	0.00032	0.085	,,
↓			
34.42	0.00000	0.000	,,
53.81	0.00313	0.828	
↓			
36.78	0.00306	0.810	jump
↓			
35.14	0.00032	0.085	,,
↓			
34.40	0.00000	0.000	,,
53.81	0.00313	0.828	
↓			
36.85	0.00306	0.810	jump
↓			
35.06	0.00000	0.000	,,

TABLE VI. Measurements of 26 May 1925.

$H_{avg.}$ (in gauss)	$W_{Hg-1925-G}$	$\frac{W}{W_{4.2}}$	Remarks
41.07	0.00000 Ω	0.000	jump
42.51	0.00015	0.004	
43.05	0.00027	0.071	,, ?
43.41	0.00039	0.100	,, ?
43.83	0.00049	0.130	,, ?
44.07	0.00064	0.169	,,
44.55	0.00083	0.220	,,
44.97	0.00103	0.273	,,
45.33	0.00108	0.286	,,
45.99	0.00127	0.336	,,
46.53	0.00140	0.370	,,
47.19	0.00166	0.439	,,
48.39	0.00184	0.489	,,
48.69	0.00201	0.532	,,
49.59	0.00230	0.609	,,
50.13	0.00296	0.783	,,
50.66	0.00313	0.828	,,
60.26	0.00313	0.828	
48.87	0.00306	0.818	,,
35.86	0.00000	0.000	,,

TABLE VII. Measurements of 5 June 1925.

$H_{avg.}$ (in gauss)	$W_{Hg-1925-D}$	$\frac{W}{W_{4.2}}$	Remarks
96.36	0.00107 Ω	0.764	
↓			
55.44	0.00102	0.728	jump
↓			
53.69	0.00100	0.714	„
↓			
50.18	0.00081	0.578	„
↓			
49.34	0.00076	0.540	„
↓			
44.56	0.00037	0.261	„
↓			
42.74	0.00031	0.218	„
↓			
41.62	0.00010	0.070	„
↓			
36.84	0.00000	0.000	„

TABEL VIII. Measurements of 12 June 1925.

$H_{avg.}$ (in gauss)	$W_{Hg-1925-L}$	$\frac{W}{W_{4.2}}$	Remarks
69.91 G	0.00000 Ω	0.000	
72.40	0.00071	0.035	
75.23	0.00364	0.179	
76.25	0.00684	0.336	
77.27	0.01169	0.574	
78.06	0.01455	0.715	
79.31	0.01519	0.746	jump?
87.13	0.01526	0.750	
113.3	0.01519	0.746	
↓			
67.87	0.01344	0.660	jump
↓			
64.35	0.00995	0.489	„
↓			
57.22	0.00000	0.000	„

TABLE IX. Measurements of 12 June 1925.

$H_{avg.}$ (in gauss)	$W_{Hg-1925-K}$	$\frac{W}{W_{4.2}}$	Remarks
69.68	0.00000 Ω	0.000	
70.24	0.00012	0.025	
70.81	0.00076	0.158	
71.38	0.00185	0.384	
72.29	0.00325	0.674	
73.42	0.00343	0.712	
73.65	0.00353	0.732	
73.98	0.00360	0.747	
74.44	0.00348	0.722	
75.00	0.00370	0.768	
75.68	0.00372	0.772	
77.61	0.00372	0.772	
84.40	0.00377	0.782	
91.43	0.00375	0.778	
↓ 64.81	0.00330	0.685	jump
↓ 61.86	0.00232	0.481	„
↓ 60.84	0.00148	0.307	„
↓ 57.56	0.00000	0.000	„
69.23	0.00000	0.000	
70.36	0.00017	0.035	
71.04	0.00042	0.087	
71.27	0.00067	0.139	
71.61	0.00141	0.293	
71.95	0.00192	0.398	
72.29	0.00232	0.481	
72.85	0.00321	0.666	jump?
73.42	0.00335	0.695	„ ?
73.65	0.00335	0.695	
73.98	0.00350	0.726	
74.78	0.00362	0.751	

TABLE X. Measurements of 3 July 1925.

$H_{avg.}$ (in gauss) Coil A	$W_{Hg-1925-P}$	$\frac{W}{W_{4.2}}$	Remarks
41.69 G	0.00007 Ω	0.029	
41.92	0.00014	0.059	
42.03	0.00022	0.092	
42.26	0.00051	0.209	
42.49	0.00127	0.525	
42.58	0.00137	0.566	
42.69	0.00165	0.683	
42.77	0.00182	0.755	
43.62	0.00203	0.841	
44.75	0.00205	0.846	
41.35	0.00003	0.012	
41.69	0.00010	0.041	
41.92	0.00021	0.087	
42.09	0.00049	0.204	
42.49	0.00126	0.520	
42.83	0.00190	0.785	
43.39	0.00203	0.841	
47.02 ↓	0.00203	0.841	
35.35	0.00131	0.540	two jumps immediately after each other
35.35 ↓	0.00007	0.031	
33.99	0.00000	0.000	jump
47.25 ↓	0.00203	0.841	
35.35	0.00131	0.540	two jumps immediately after each other
35.35 ↓	0.00008	0.034	
33.88	0.00000	0.000	jump

TABLE XI. Measurements of 3 July 1925.

$H_{avg.}$ (in gauss) Coil W	$W_{Hg-1925-P}$	$\frac{W}{W_{4.2}}$	Remarks
40.70	0.00003	0.012	
41.04	0.00006	0.024	
41.56	0.00025	0.102	
41.92	0.00143	0.590	
42.06	0.00148	0.612	
42.12	0.00190	0.785	
42.26	0.00198	0.821	
43.26	0.00203	0.841	
↓			
56.70	0.00203	0.841	
↓			
35.70	0.00131	0.540	jump
↓			
34.80	0.00000	0.000	„
40.70	0.00005	0.02	
41.06	0.00005	0.02	
41.76	0.00069	0.285	
41.98	0.00144	0.597	
42.48	0.00203	0.841	
56.70	0.00203	0.841	
↓			
35.80	0.00131	0.540	jump
↓			
34.78	0.00010	0.041	„
↓			
33.56	0.00000	0.000	„

Physics. — "*On the magnetic disturbance of the supraconductivity with mercury*". II. By W. J. DE HAAS, G. J. SIZOO and H. KAMERLINGH ONNES. (Comm. N⁰. 180*d* from the Physical Laboratory at Leiden).

(Communicated at the meeting of December 19, 1925).

§ 3. *The measurements* (continued).

The results of the measurements, contained in the preceding paragraph [1]) left no doubt as to the existence of the hysteresis and of the discontinuities in the disturbance of the supraconductivity of mercury, with the aid of a homogeneous magnetic field. It was also ascertained, that the cause of the different results as to the height and the situation of the jumps in the descending lines and as to the continuity or discontinuity of the ascending lines, was not to be found in the nature of the magnetic field, but in the resistances themselves.

We were therefore led to the supposition that the nature of the hysteresisfigures might be determined by the crystalline state of the resistances. By the slow cooling the thread in the capillary may be formed of a few single-crystals and the sudden disappearance of the resistance of such a crystal might be the reason of a "jump".

The fact that different crystals loose their resistance at different values of the magnetic field might be due to the different orientation of the crystals in reference to the magnetic field.

This suggestion may be tested in the following ways:

1⁰. The same resistance, measured on different days would not attain the same state of crystallisation and would thus give a different result as to the form of the hysteresisfigure.

2⁰. The hysteresisfigure of a real single crystal wire would probably show a single nature.

3⁰. By measuring the resistance between different points of the thread it would be possible to decide if the change in resistance, which corresponds to a jump, is local, or is spread over the whole length of the thread.

To obtain an answer to these three questions, the following measurements were carried out:

7. *Measurements of* 16 *July* 1925.

a. Resistance *Hg*—1925—*G'*, length 24 mm., diameter 0.0052 mm., type I. This was made with the capillary from the resistance *Hg*—1925—*G* measured 26 May 1925, to which new reservoirs were blown and then again filled with mercury.

The field was applied with coil *W*. For the data of the inhomogeneity

[1]) These Proceedings 29 1926, p. 233.

of the field, the measurements of 26 May 1925 may be referred to. The measurement was made at a temperature of 3°.962 K., with two directions of the field namely the first time in the same direction as the vertical component of the earth's field, the other time in the opposite direction. See tables XII and XIII, and figure 7.

TABLE XII. Measurements of 16 July 1925.

$H_{avg.} \underset{N}{\overset{Z}{\uparrow}}$ (in gauss)	$W_{Hg-1925-G'}$	$\frac{W}{W_{4.2}}$	Remarks
73.12 G	0.00000 Ω	0.000	
73.48	0.00023	0.057	
73.69	0.00089	0.215	
73.84	0.00133	0.323	
74.12	0.00241	0.585	
74.26	0.00269	0.651	
74.41	0.00301	0.729	
75.12	0.00305	0.740	
76.54	0.00305	0.740	
100.06	0.00301	0.729	
↓ 68.35	0.00283	0.687	jump
↓ 65.07	0.00000	0.000	jump

TABLE XIII. Measurements of 16 July 1925.

$H_{avg.} \underset{Z}{\overset{N}{\uparrow}}$ (in gauss)	$W_{Hg-1925-G'}$	$\frac{W}{W_{4.2}}$	Remarks
70.84 G	0.00007 Ω	0.000	
74.41	0.00027	0.065	
74.90	0.00166	0.403	
75.12	0.00196	0.475	
75.55	0.00302	0.732	
76.33	0.00303	0.735	
99.35	0.00302	0.732	
↓ 69.63	0.00115	0.687	jump
↓ 66.42	0:00000	0.000	jump

The influence of reversing the field exists in a shifting of the figure in the $\frac{W}{W_{4.2}}$, *H diagram over a distance which falls within the limits of accuracy of the measurement.*

In fig. 7 the lines are given uncorrected for the earth's field. Therefore the transition curves are shifted about one gauss in reference to each other. That this displacement is not exactly equal to twice the vertical

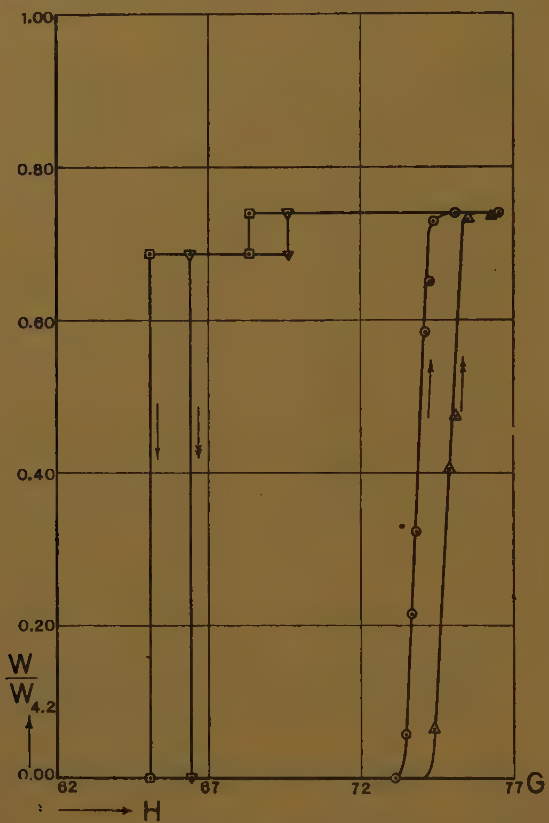

Fig. 7.

⊙ □ } Field N ↑ Z   △ ▽ } Field Z ↑ N

component of the earth's field is not to be wondered at, owing to the inhomogeneity of the field and to the fact that the temperature is never quite constant. [1])

Though *Hg*—1925—*G* and *Hg*—1925—*H'* may not be considered as

[1]) Except with the measurements, contained in table XIII the south-pole of the coil was always turned upwards. Therefore to all given values of *H*, the vertical component of the earth's field should be added. This correction is omitted, however, because it falls within the limits of the absolute accuracy of the values of *H*. The relative accuracy which depends on the accuracy with which the current strength is measured is, of course, considerably higher.

the same resistances [1]), still in both cases length and diameter of the thread and orientation in the magnetic field are the same, so that the results obtained with Hg—1925—G and Hg—1925—G' may be obviously compared. (fig. 4 and 7). Although there seems to be a similarity in the nature of the descending line — which is remarkable enough, but may be only a coincidence — the difference in the ascending lines is obvious. Namely Hg—1925—G', contrary to Hg—1925—G, shows here no discontinuities. It seems allowable to consider this result as a confirmation of the suggestion mentioned under *a*).

b. Resistance Sn—1925—K_1. This is a single-crystal tinwire, from a collection of single-crystal wires kindly sent to us by Prof. SCHMIDT of Berlin, to whom we acknowledge our thanks.

We had no information as to the orientation of the crystal-axis in reference to the direction of the thread and as this was only a preliminary measurement, we did not try to determine this orientation. The length of the wire was 6 cm., the diameter 0.75 mm. The resistance at roomtemperature amounted to 0.163 Ω; at 4°.20 K. to 447 $\times 10^{-8}$ Ω [2]).

The field was applied with coil A and therefore notwithstanding the great length of the wire was aproximately homogeneous.

$$A_{max.} = 0.992 \quad A_{min.} = 0.988 \quad \frac{A_{min.}}{A_{max.}} = 0.998$$

$$A_{gem.} = 0.990 \quad H_{gem.\,(\text{in gauss})} = 113.1\, i$$

(i in Ampères).

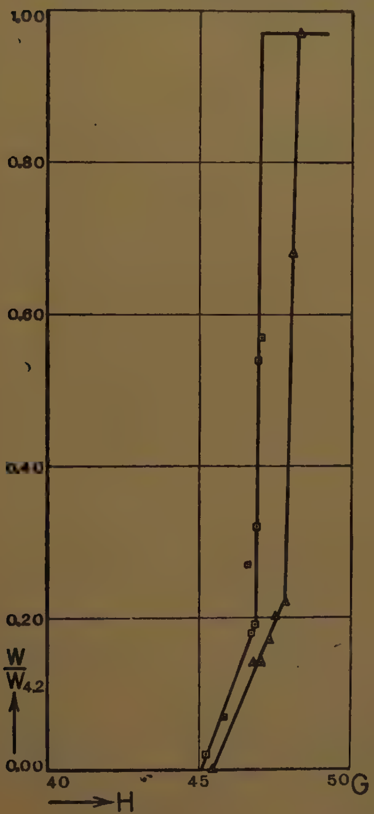

Fig. 8.

The measurements were made at 3°.424 K. Because of the small resistance of the thread at heliumtemperatures, the use of a high measuring current was necessary (0.9 Ampère). Through lack of time the hysteresiscurve could not be so completely determined as would have been desirable. See table XIV and figure 8. The form of hysteresisfigure, as far as it may be derived from the complete measu-

[1]) In § 1 it has already been observed, that by the repeated breaking of the resistances, we did not succeed in measuring one and the same resistance on different days. The formerly used construction (Leiden, Comm. N° 133*a*) with which this defect was sufficiently avoided, for these measurements was not suitable for other reasons (necessity of a homogeneous and unidirectional field over the whole conductor).

[2]) The ratio between these two values amounts to 0,00027. For extruded tinwires it amounts to about 0.0008.

rements recalls the figures obtained with extruded tinwires but differs from those by its *greater simplicity* [1]). The ascending as well as the descending lines seems to consist only of two linear parts. Though no real jump was observed, the upper parts of the transition line differ so little from the axis of the ordinates, that we are inclined to ascribe this difference to the inhomogeneity of the field.

c. Resistance *Hg*—1925—0, length 20 mm., diameter 0.035 mm., type II, placed within coil *A*. At 3°.797 K the hysteresisfigure was determined

TABLE XIV. Measurements of 16 July 1925.

H_{avg} (in gauss)	$W_{Sn-1925-K_1}$	$\frac{W}{W_{4.2}}$	Rèmarks
47.50 G	0.0000009 Ω	0.21	
55.42	433	0.97	
46.94	244	0.54	
46.88	144	0.32	
46.82	83	0.19	
46.71	78	0.18	
45.81	31	0.07	
44.11	00	0.00	
45.41	00	0.00	
46.77	61	0.14	
47.05	61	0.14	
47.33	78	0.17	
47.84	100	0.22	
48.07	305	0.68	
48.29	433	0.97	
84.83	444	0.99	
47.05	255	0.57	
46.60	122	0.27	
45.24	11	0.02	

[1]) See Comm.: On the magnetic disturbance of tin. These Proceedings 29 (1926) p. 221. We state, however, that the figures contained in that communication are obtained with a not very homogeneous field, which besides was not quite longitudinal, but imperfectly transversal. The question as to how an extruded tinwire behaves in a homogeneous and perfectly longitudinal field has, therefore, still to be investigated.

and also some measurements were made of a hysteresiscycle with end-values of H, at which the resistance had not quite disappeared or not quite returned.

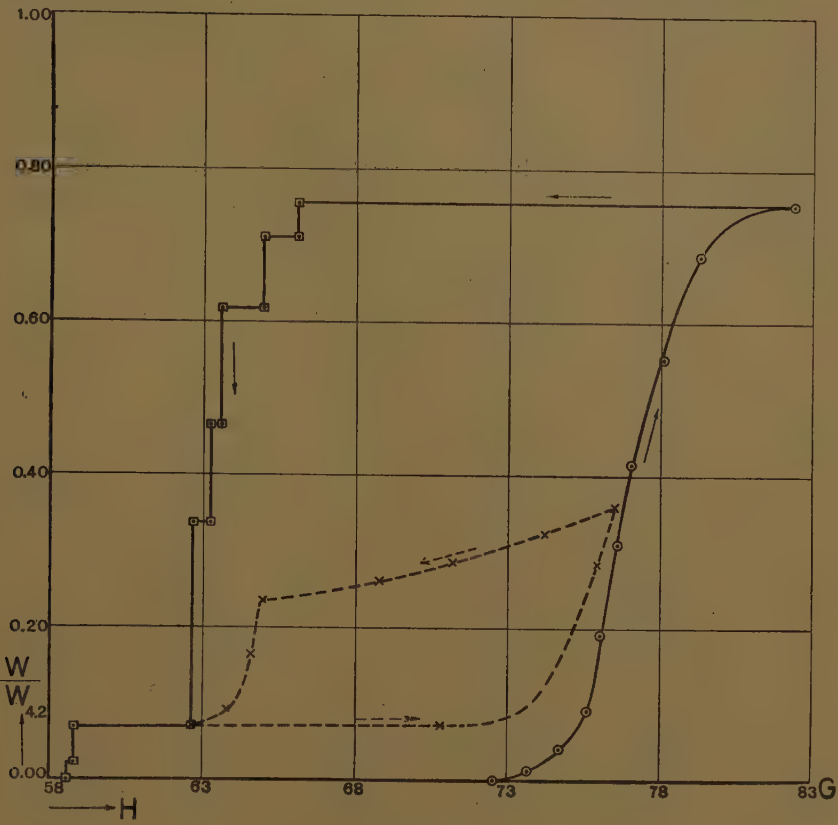

Fig. 9.

Compare the measurement of 5 June 1925 c.

Results contained in table XV and represented by figure 9. The dotted lines represented the measurement of the partial hysteresis. Sharp discontinuities were not observed here.

Fig. 10.

8. *Measurements of* 3 *Dec.* 1925.

This was carried out with resistance *Hg—1925—Z*, consisting of two capillaries (*a* and *b*), connected by a mercury reservoir provided with platinum wires, so that the resistances of both capillaries could be determined separately and together (*c*).

At roomtemperature we found: for *a*: 2.499 Ω, for *b*: 3.740 Ω, for *c*: 6.240 Ω. At a temperature of 4°.2 K: for *a*: 0.00137 Ω, for *b*: 0.00182 Ω and for *c*: 0.00321 Ω.

At 3.883° K. the hysteresisfigure was determined. The return of the resistances was again continuous, its disappearance discontinuous. When a jump in the combined resistance (*c*) was found, it appeared, with but one exception, that only one of

TABLE XV. Measurements of 16 July 1925.

$H_{avg.}$ (in gauss)	$W_{Hg-1925-O}$	$\frac{W}{W_{4.2}}$	Remarks
72.51 G	0.00000 Ω	0.000	
73.65	0.00012	0.041	
74.66	0.00038	0.091	
75.57	0.00086	0.191	
76.02	0.00180	0.310	
76.59	0.00292	0.415	
77.04	0.00392	0.415	
78.04	0.00520	0.551	
79.31	0.00648	0.687	
82.37	0.00711	0.754	
117.27	0.00711	0.754	
↓ 66.05	0.00670	0.711	jump
↓ 64.92	0.00581	0.617	"
↓ 63.56	0.00438	0.465	"
↓ 63.22	0.00318	0.337	"
↓ 62.65	0.00065	0.069	"
↓ 58.80	0.00021	0.022	"
↓ 58.58	0.00000	0.000	"
117.27	0.00711	0.754	
↓ 62.65	0.00065	0.069	jump
70.81	0.00068	0.072	
75.91	0.00267	0.283	
76.25	0.00337	0.358	
74.21	0.00305	0.324	
71.15	0.00271	0.287	
68.77	0.00264	0.261	
64.92	0.00222	0.235	
64.58	0.00154	0.163	
63.84	0.00086	0.091	
63.45	0.00079	0.084	

the capillaries has lost a part of its resistance. Only in the case of the first jump did both capillaries loose a part of their resistance. We cannot yet decide whether special significance is to be attributed to this exception or whether it is a mere coincidence.

At any rate the changes of the resistances in *a* and *b* are not at all proportial to the resistances of *a* and *b* before the jump, so that there is no question of a continuous distribution of the changes of resistance over the whole length of the capillaries. At somewhat higher temperature, $T = 3^{\circ}.895$, the descending line alone was once again measured. About the same jumps appeared, except that the first two jumps in the capillary *a* were now combined to one. See table XVI and fig. 10. In the figure it is indicated if the jumps belonged to capillary *a* or *b*. As ordinate the combined resistance of both capillaries is plotted.

4. *The measurements* (continued).

In § 2 attention was directed to the fact that in the magnetic field only a part of the resistance at $4^{\circ}.20$ K. (above the vanishing-point) may

TABLE XVI. Measurements of 3 December 1925.

T	$H_{avg.}$ in gauss	$W_{Hg-1925-Z}$ a.	$W_{Hg-1925-Z}$ b.	$W_{Hg-1925-Z}$ c.	Remarks
$3^{\circ}.883$K.	58.24	0.00015	0.00025	0.00041	
	58.80	0.00053	0.00077	0.00129	
	59.48	0.00107	0.00132	0.00239	
	61.52	0.00109	0.00137	0.00251	
	↓ 51.10	0.00062	0.00103	0.00167	jump
	↓ 50.87	0.00039	0.00104	0.00142	„
	↓ 50.53	0.00037	0.00045	0.00082	„
	↓ 47.70	0.00000	0.00042	0.00042	„
	↓ 46.45	0.00000	0.00000	0.00000	„
$3^{\circ}.895$K.	63.45	0.00107	0.00139	0.00250	
	↓ 49.40	0.00044	0.00104	0.00147	jump
	↓ 48.95	0.00044	0.00045	0.00087	„
	↓ 46.68	0.00000	0.00045	0.00045	„
	↓ 45.89	0.00000	0.00000	0.00000	„

be brought back and that the amount of this fraction depends on the temperature. [1])

To obtain more information about the nature of this dependency, a special measurement was made.

9. *Measurements of 20 Nov. 1925.*

Resistance *Hg.*—1925—*N*, length 15 mm., diameter 0.04 mm., type II. The change of the resistance was first followed in the temperature

TABLE XVII. Measurements of 20 November 1925.

p_{He} in mm Hg	T	$W_{Hg-1925-N}$
874.5	4.35 K	0.005478 Ω
845.1	4.31	0.005418
822.1	4.28	0.005305
798.3	4.25	0.005180
784.5	4.23	0.005107
751.0	4.188	0.004836
749.2	4.184	0.004513
744.8	4.180	0.003916
743.5	4.178	0.002926
738.3	4.172	0.000942
736.1	4.168	0.000527
734.8	4.164	0.000223 [1])
729.9	4.159	0.000000

TABLE XVIII. Measurements of 20 November 1922.

p_{He} in mm Hg	T	$(W_{Hg-1925-N})_{max.}$
614.9	3.99 K	0.004387 Ω
393.5	3.60	0.003259
166.9	3.01	0.002021
59.8	2.48	0.001451
29.9	2.19	0.001277
4.3	1.56	0.001041

[1]) Cf. also Leiden Comm. V. Suppl. N⁰. 44, § 2 and N⁰. 50 § 3.

region between 4°.35 K. and 4°.159 K.[1]). At the last temperature the resistance has fallen below the limits of measurement. The sudden diminuation of the resistance ("vanishing-point") lies between 4°.19 K. and 4°.16 K. table XVII. Then at six lower temperatures, by applying a sufficiently strong magnetic field, the maximum value of the resistance which could be brought back was determined. (table XVIII).

Though the fields applied were at least sometimes stronger than that which is just sufficient to bring back the maximum value, they were not sufficient to show clearly the increase of the normal resistance, which appears in much stronger fields (of some kilo-gauss for example).

In fig. 12 the continuous line represents the measurements of table XVII and the dotted line those of table XVIII.

The latter forms a continuation of that part of the former, lying above the vanishing-point. The dotted line shows, as far as it could be drawn,

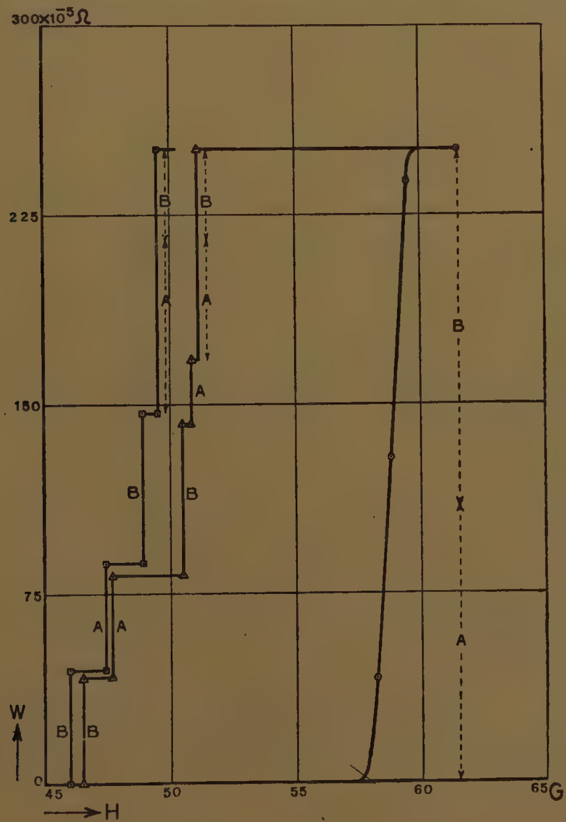

Fig. 11.

quite the character of a resistance-curve of a non-supraconducting metal at those temperatures.

Nothing can yet be said with certainty as to the course of this line below the lowest measured point.

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1) Cf. also Leiden Comm. N⁰. 124, p. 23, § 23 and N⁰. 133a p. 21.

TABLE X

Date	Resistance	Type	Length	Diameter	$W_{room temp.}$	$W_{4^{0}.2\ K.}$	$\frac{W_{4.2}}{W_{K.}}$	Field	$\frac{A_{n}}{A_{n}}$
18- III-1925	Hg-1925-A	I	11.5 cm.	0.092 mm.	14.93 Ω	0.00710 Ω	0.000475		
30-IV-1925	Hg-1925-C	I	8.3 „	0.2 „	2.648			coil W	0.8
15- V-1925	Hg-1925-E	I	8.3 „	0.2 „	2.636	0.00105	0.000398	„	0.8
								electromagnet	
26- V-1925	Hg-1925-G	I	2.4 „	0.052 „	8.20	0.00378	0.000461	coil W	0.9
								„	0.9
								„	0.8
5-VI-1925	Hg-1925-D	I	8.3 „	0.18 „	3.128	0.00140	0.000448	„	0.8
12-VI-1925	Hg-1925-L	II	1.8 „	0.022 „	35.14	0.0204	0.000581	coil A	1.0
	Hg-1925-K	II	1.8 „	0.045 „	8.22	0.00482	0.000586	„	1.0
3-VII-1925	Hg-1925-P	II	1.0 „	0.045 „	4.441	0.00242	0.000545	„	1.0
								coil W	0.9
16-VII-1925	Hg-1925-G′	I	2.4 „	0.052 „	8.08	0.00412	0.000510	„ W|Z/N	0.9
								„ W|N/Z	0.9
	Hg-1925-O	II	1.5 „	0.035 „	16.01	0.00943	0.000589	„ A	1.0
20- XI-1925	Hg-1925-N	II	1.5 „	0.04 „	9.89	0.00490	0.000495	„ W	–
3-XII-1925	Hg-1925-Z a	II	1.1 „	0.063 „	2.499	0.00137	0.000548	„ A	1.0
	„ b	II	0.9 „	0.053 „	3.741	0.00182	0.000487		1.0

IMARY OF DATA

	Ascending line	Descending line	$(H_{1/2})_{asc.}$	$(H_{1/2})_{desc.}$	Breadth of the hysteresis-figure	$\left(\frac{W}{W_{4.2}}\right)_{max.}$	Table	Figure
5 K.	continuous?	2 jumps?	25 G.	22.5 G.	2.5 G.		I	
	„	7(?) „	77	72	5	0.70	II	
	„	6(?) „	72	59	13	0.71	III	
	8 jumps	2 „	74.5	66.5	8	0.74	IV	3
	11 „	2 „	42	35	7	0.82	V	4
	15 „	2 „	48.5	36	12.5	0.83	VI	4
	?	8 „	?	44.5	?	0.77	VII	—
	continuous	3 „	77	65	12	0.78	VIII	5
	„	4 „	71.5	62	9.5	0.75	IX	5
	„	3 „	42	35.3	6.7	0.84	X	6
	„	3 „	41.5	34.8	6.7		XI	6
	„	2 „	75	66.5	8.5	0.72	XII	7
	„	2 „	74	65	9		XIII	7
	„	8 „	77.5	63.5	9	0.73	XV	9
	—	—	—	—	—	—	XVII & XVIII	12
	„	3 „	59	50.5	8.5	0.78	XVI	11
	„	3 „	59	50.5	8.5	0.75	XVI	11

The result of this measurement may be expressed in this way.

When a supraconductor is placed in a sufficiently strong magnetic field, the resistance curve of a supraconductor shows no anomalies. [1])

§ 5. *Discussion.* [1])

To facilitate the survey of the results obtained, in table XIX, as much data as possible of the used resistances are summarised. This table especially brings out the different behaviour of the resistances in reference

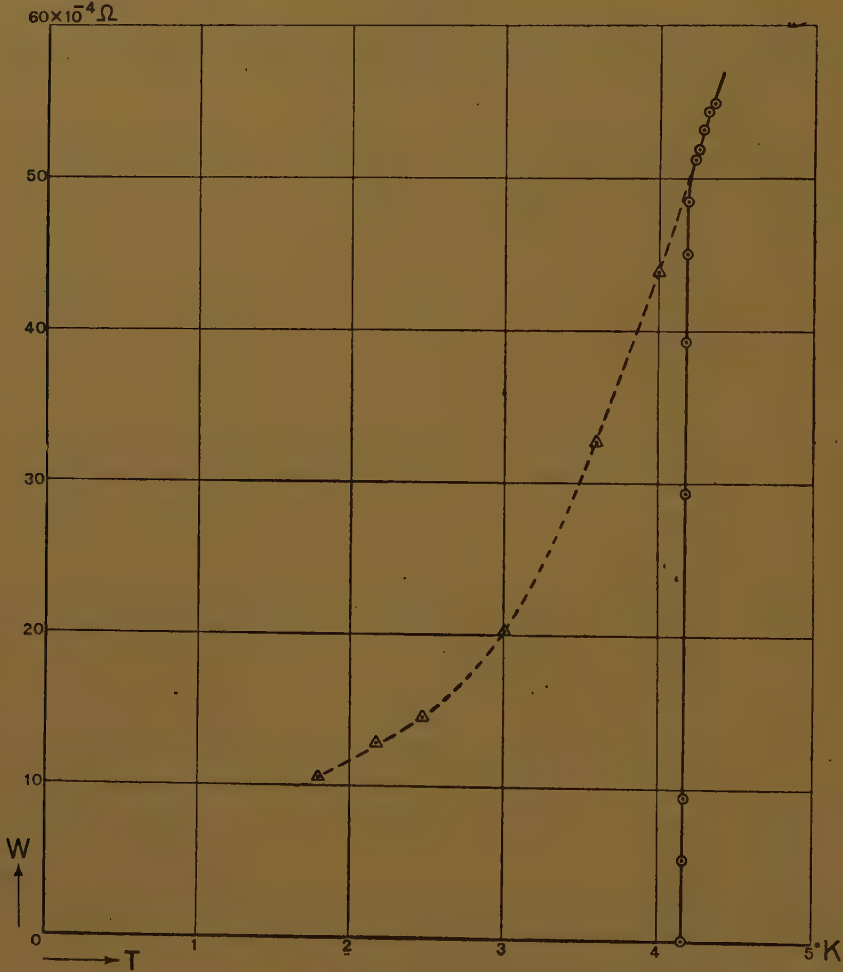

Fig. 12.

to the number of jumps in the descending line. In the ascending line discontinuities are found with one resistance. Further the individual character of the resistances is clear from the very different values of $\frac{W_{4.2}}{W_{roomtemp.}}$,

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[1]) Cf. Leiden Comm. Suppl. N⁰. 50 § 3 p. 11 and especially the result obtained for an alloy of Pb and Sn (Dissertation TUYN, Leiden 1924 p. 24, fig. 10 p. 65).

[2]) Cf. also Suppl. 44a fig. 4.

that is the ratio of the values of the resistance at 4°.2 K. and at room-temperature. This is in agreement [1]) with the known fact that with the freezing of mercury also very different values of the ratio of the resistances in the liquid and in the solid state are found. Further in the table are given the values $(H^1/_2)_{asc.}$ and $(H^1/_2)_{desc.}$, i.e. the values of the magnetic field at which the resistance has half reappeared and half disappeared respectively.

These values appear to agree rather well for the various resistances at the same temperature (the differences found amount to some percents).

The difference between $(H^1/_2)_{asc.}$ and $(H^1/_2)_{desc.}$ is given as breadth of the hysteresisfigure. This appears to differ somewhat for the various resistances. The breadth increases a little with decreasing temperature. Finally the values of $\left(\frac{W}{W_{4.2}}\right)_{max.}$ are given, that is, the part of the resistance at 4°.20 K. which can be brought back with the magnetic field. These numbers also agree to some percents, at the same temperature.

It has already been observed that we are inclined to look for the cause of the found differences between the various resistances in variations of the crystalline state, perhaps in the existance of some, differently orientated, pieces of single crystal wire.

The investigation of the properties of the supraconductors in the form of single crystalwires has therefore become very urgent and has already been taken up again. [2])

[1]) Cf. also Leiden Comm. N⁰. 153*a* p. 12 and N⁰. 142*a* p. 5.

[2]) The resistance of Cu-crystals, kindly provided by Prof. W. WIEN, has already been measured here, a long time ago. (Cf. Dissertation W. TUYN, p. 58 and 59). First preliminary measurements with single-crystal wires, received from the Philips' Glowlamp Works, Eindhoven, were performed in 1913 (l.c. p. 9).

Physics. — *"The absorbtion bands of the compounds of the rare earths, their modification by a magnetic field, and the magnetic rotation of the plane of polarisation at very low temperatures"* [1]). (Communication N⁰. 177 from the Physical Laboratory, Leiden.) By J. BECQUEREL, H. KAMERLINGH ONNES and W. J. DE HAAS.

(Communicated at the meeting of November 28, 1925).

§ 1. *Materials.* Our experiments have reference to four optically uniaxial crystals:

xenotime ((Y, Er, Ce) PO_4);
tysonite ((Ce, La, Nd + Pr) F_3) ;
parisite ((Ce, La, Nd + Pr) Ca F_2 $(CO_3)_3$) ;
bastnaesite ((Ce, La, Nd + Pr)$_2$ $(CO_3)_3$ (Ce, La, Nd + Pr) F_3).

§ 2. *Cryogenic apparatus.* The cryostats were similar to those used in 1908 [2]). For the helium experiments the double vacuum glass must be surrounded by a third, and in this connection we were again dependent to a high degree on the skill of Mr. KESSELRING, head of the large glass-blowing workshop of the Physical Laboratory. Within an external diameter of not more than 14.25 mm. he was able to bring together six perfectly concentric glass tubes, pairs of which formed the lower, closed ends, of the vacuum glasses, having also concentric, but much wider upper parts, constituting together our cryostats in this case. It was therefore possible to bring the poles of the electromagnet to within 20—18 mms. of each other, a matter of great importance for the obtaining of strong fields [3]).

The outside glass was filled with liquid air or nitrogen; when experiments were made in the magnetic field it was only necessary to protect it with a light cover from filling with frozen moisture. The middle

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[1]) This communication contains the contents of the three communications presented to the meeting of 27 July 1925 and recorded on page 657 of the Zittingsverslag.

[2]) JEAN BECQUEREL and H. KAMERLINGH ONNES, these Proceedings 10, 592, Leiden Comm. No. 103.

[3]) The large WEISS electromagnet (tested by WOLTJER, these Proc. **26**, p. 613; Leiden Comm. N⁰. 167b), made by Messrs. OERLIKON for Leiden, was used for some of the experiments, but for the greater number another magnet was used which differed only slightly from the former and was made by the same for the "Muséum National d'Histoire naturelle" of Paris. By regulating the current through the windings a constancy of the field strength of certainly 0,2 % could be established. The strength of the field was determined from the ZEEMAN-effect on line 5221 Å. (8.53 times normal) produced in a xenotime plate in liquid N_2 placed in the same place as the crystal plate. The inhomogeneity of the field appeared from observations with tysonite not to amount to more than 0.15 %.

glass was reserved for filling with liquid hydrogen and was fitted with a cap provided with two openings for the inlet and outlet of hydrogen during the filling. This was done in another room, from which the filled cryostat was conveyed to the room for the optical experiments. Here the evaporating hydrogen was led outside the room through an outlet tube coupled to the cap. The innermost of the three vacuum glasses, destined for the reception of the liquid helium, was provided with a metal cap carrying a helium inlet similar to that used to introduce helium into transportable cryostats [1]). The evaporating helium was collected in a gasholder (during the transport in rubber balloons). When working at 20° K. the inner, as well as the middle, glass was filled with hydrogen. If it was required to work between 20° and 14° K., then the outlet tube of the inner glass was connected to a vacuum lead, whence by closing the inlet tube, the vapour pressure corresponding to the wished for temperature could be obtained.

§ 3. *Optical apparatus.* As a source of light the very intense light from an arc lamp having a fairly constant position of the crater, described by ZEEMAN [2]) was used, although later this was replaced by a Zeiss arc lamp giving a less intense light, but in which the crater remained exactly in the same place, and whose carbons could be more readily changed.

The crystals were fixed, as formerly, with wax in small holes in a strip of platinum, which hung from a glass rod passing through the cover of the cryostat, so that they had the right alignment to the horizontal. The horizontal alignment could be altered by the observer by rotating in a vertical axis with the help of a Hooke's key.

For the calibration of the wave lengths a neon lamp was used for the red and orange, and an iron lamp for the remainder of the spectrum.

We used a spectrometer having a plane Rowland grating and a lens of a focal length of 1.30 m. adjusted for autocollimation.

§ 4. *Results.* The following contains the general, most obvious, results whose details will be studied on the plates obtained.

a. Effect of temperature alone. In the experiments made at Leiden in 1908 [3]) it was stated that the spectra of crystals of the rare earths, very rich in absorbtion bands at the temperature of liquid air [4]), become simpler when the temperature is lowered to the freezing point of hydrogen (14° K.). At the boiling point of helium (4°.2 K.) the spectra are, on the whole, still somewhat simpler. Several bands which show a maximum of absorbtion at a more or less low temperature, and which are still visible at 14° K. have completely disappeared. On the contrary, there exist bands

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1) Conseil de Physique Solvay, Brussels, April 1924. Leiden Comm. Suppl. No. 50*a*.
2) Diss. Leiden, 1893.
3) JEAN BECQUEREL and H. KAMERLINGH ONNES, l.c.
4) JEAN BECQUEREL, le Radium, 4, 328, 1907.

which, appearing only at low temperatures, increase in intensity down to the temperature of liquid helium; it is possible that these pass through a maximum at a still lower temperature.

b. Resolving of the bands in a magnetic field. We have studied down to 4°.2 K. the effect of a magnetic field on the absorbtion bands, confining ourselves for the present to the case in which the optical axis is orientated along the lines of force and in which the light passes through the crystal in the same direction (named the "longitudinal" case).

Under these conditions the "ordinary" spectrum is obtained, and the components resulting from the resolution of the bands in the magnetic field correspond to the absorbtion of circular vibrations.

Figures 1 and 2 show two groups of bands of xenotime, at temperatures of 20° K. and 4°.2 K., one in the red and the other in the green; the notes explain the various juxtaposed spectra. The spectra of the circular vibrations of opposite signs have been brought under one another by the use of a rhomboid of calcspar placed in front of the slit of the spectroscope and preceded by a quarter wave-plate. The strength of the field used was 26.17 kilogauss.

A fact that had been expected, but which had required verification, was that the variations of the period, produced by the magnetic field, were independent of the temperature, a result which had previously been confirmed as far as 14° K.

A remarkable phenomenon was the accentuation of the dissymmetry in the intensities of the components corresponding to oppositely circularly waves. This dissymmetry at very low temperatures, first

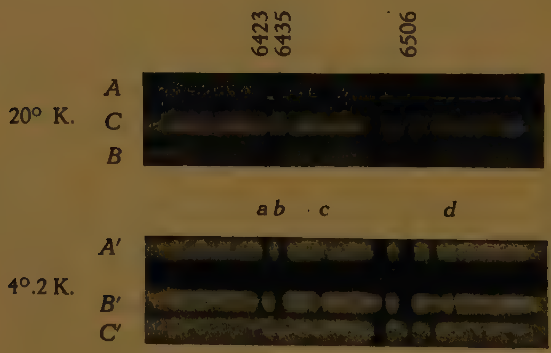

Fig. 1.

Xenotime. Group of absorbtion bands in the red. First order spectrum, approx. twice enlarged.

A. Spectrum without magnetic field at 20° K.
A'. „ „ „ „ „ 4°.2 K.
B. „ in a field of 26.17 kilogauss for circularly polarised light of the same sign as the current passing through the coils of the electromagnet, at a temperature of 20° K.
B' ditto, at 4°.2 K.
C As *B*, but with the incident light polarised in the opposite sense.
C' As *B'*, „ „ „ „ „ „ „ „ „

observed at the temperature of liquid air [1]), has already been studied down to the melting point of hydrogen [2]). At 4°.2 K. it becomes so strong that in

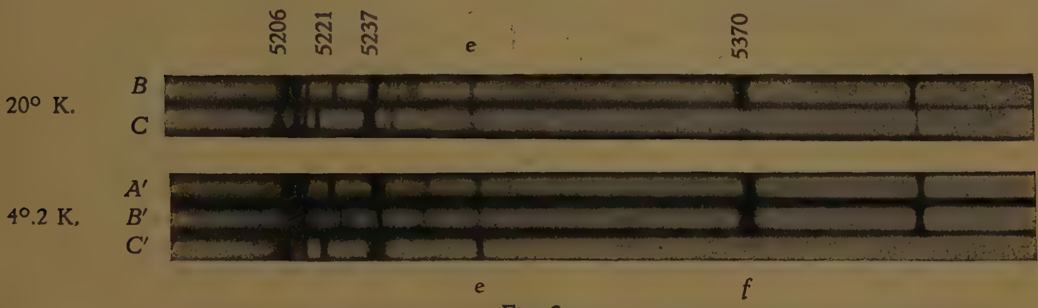

Fig. 2.

Xenotime. Group of absorbtion bands in the green. Second order spectrum, approx. twice enlarged.

A′ Spectrum without magnetic field at 4°.2 K.

B—C. Juxtaposed spectra of the two circular vibrations of opposite sign in a field of 26.17 kilogauss (*B*, having the same sign as the coil current) at 20° K.

B′—C′. As above but at 4°.2 K.

a field of 25 kilogauss the spectra of two oppositely circularly polarised rays have a completely different appearance. This is the case with xenotime as is seen from figures 1 and 2; for some bands, (e.g. *a, b, c,* and *d* of fig. 1, and *f* of fig. 2) only those components displaced towards the side of shorter wave lengths remain [3]). In weak fields the dissymmetries of the intensities appear long before the separation of the components is visible.

Down to a temperature of 14° K. it appears to be a rule that the tendency to dissymmetry is shown by an increase in intensity of the components displaced towards the shorter wave lengths. Of the dissymmetries of an opposite sign, which are to be observed at ordinary temperatures and even at the temperature of liquid air, the greater number have changed their sign at the boiling point and freezing point of hydrogen, the others are diminished in magnitude, so that a change of sign at a still lower temperature is to be expected. The latter has usually been found, but it is a noteworthy fact that two exceptions to this rule have been noted, one in the case of a band of tysonite in the red, the other for a band (very insensitive from the point of view of alteration of the period) of xenotime; the latter is indicated by *e* in fig. 2, at 20° K. the component displaced towards decreasing wave length is the more intense, at 4°.2 K.

1) Jean Becquerel, le Radium, 5, 9, 1908.

2) Jean Becquerel ond H. Kamerlingh Onnes, l.c.

3) To some of these bands (e.g., *a* and *b*) at first sight there seem to correspond in the juxtaposed spectrum very weak components (invisible in the reproductions). Actually the latter are the small wave length components of a secondary doublet polarised in the opposite sense to the main doublet; in other words the bands in question form a quadruplet, or more exactly, two doublets, and at 4° 2 K. only one component of each remains.

the opposite is the case. Another band (in the extreme violet of the spectrum of tysonite) shows a singular phenomenon. The component of shorter wave length is finer, but at the same time more intense than the other, so that one cannot say, from the appearance of the spectrum alone, which component corresponds to the greater amount of light absorbed. With the exception of these special cases the dissymmetries of the intensities observed up to the present all conform to the rule indicated above, but this rule cannot be considered as a general law, as one might have been led to expect from the experiments made at less low temperatures.

c. *Magnetic rotation of the plane of polarisation.* One of us studied in 1907 the magnetic rotatory power of tysonite and of parisite and established that the so-called negative rotatory power increases between room temperature and liquid air temperature at a rate approximately inversely proportional to the absolute temperature [1]). An obvious combination of this observation with the law of Curie relating to the magnetic susceptibility suggests that the rotation in these crystals, which are paramagnetic, varies proportionally with the degree of magnetisation [2]), so that the series of optical experiments which we have made, forms part of a wider programm being carried out at Leyden which includes the series of experiments on the paramagnetism of crystalline salts at low temperatures as well as the Röntgen spectra of the crystal-lattices of these bodies. The experiments carried out at Leyden in 1908 [3]) confirmed and extended this result to 20° K.

The increase of the magnetic rotatory power continues down to 4°.2 K., and from this point of view tysonite is especially remarkable.

Fig. 3 shows the fluted spectrum obtained at 4°.2 K. between crossed nicols, in a field of 23.60 kilogauss, with a crystal only 1.673 mms. thick. The rotation is as much as 5 π in the red and reaches 20 π in the near ultra violet. Groups of bands sensitive to the magnetic field bring about local disturbances, for example the band *g* in the yellow is not an absorbtion band but an abnormal, rather fine, fluting one, which results from a rapid decrease of the magnetic rotatory power as the edge of the absorbtion band *h* is approached (compare the curvature of the fringes in fig. 5 in which the absorbtion band in question has been again indicated by the letter *h*).

Fig. 4 represents the fluted spectra obtained with the same crystal in a field of the same order of magnitude (about 22.50 kilogauss) but at the temperature of liquid hydrogen. In the visible spectrum there are only four wide flutes to be seen (the rotation is π in the red and 4 π in the extreme violet).

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[1]) JEAN BECQUEREL, le Radium, 5, 5, 1908.

[2]) A result already found for thin plates of iron, nickel, and cobalt by KUNDT, Wied, Ann. 27, 191, 1886, and DU BOIS, ibid. 31, 941, 1887.

[3]) JEAN BECQUEREL and H. KAMERLINGH ONNES, l. c.

Fig. 5 represents, by another method, the magnetic rotation and the rotatory dispersion of the same plate from the orange to within the blue (1st. order spectrum) at 4°.2 K. and in a field of 23.82 kilogauss. It was obtained by the method of "fringes" [1] : the incident light was rectilinearly polarised (in an optinal direction) ; having passed through the crystal, in which it was split into two circular waves of different refractive index, the light passed through a quarterwave plate whose main axes were at 45° to the horizontal, and then through a Babinet compensator gummed to the slit of the spectroscope and so orientated that the fringes became horizontal (cutting the slit at right angles), and finally through a nicol placed at 45° behind the slit. The difference in path between two rays, circularly polarised in opposite directions after passing through the

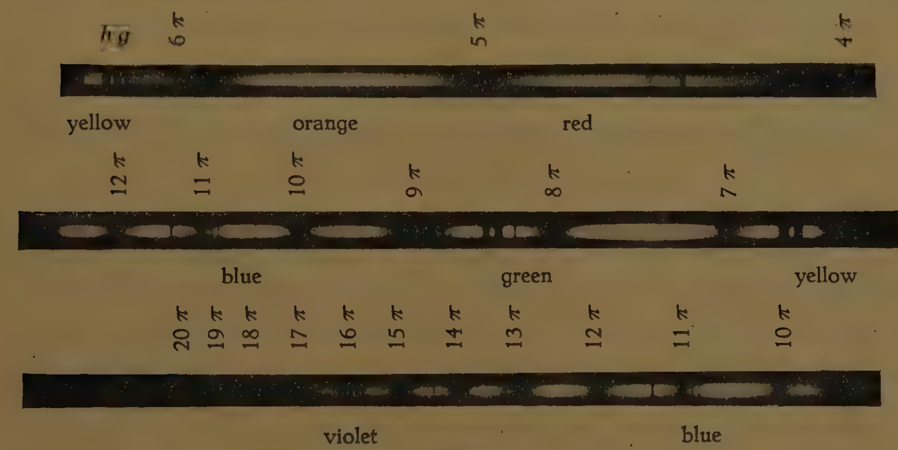

Fig. 3.

Tysonite, fluted spectrum in a magnetic field (actual size).
$H = 23$ kilogauss approx., thickness of crystal 1,67 mm. $T = 4^\circ.2$ K.

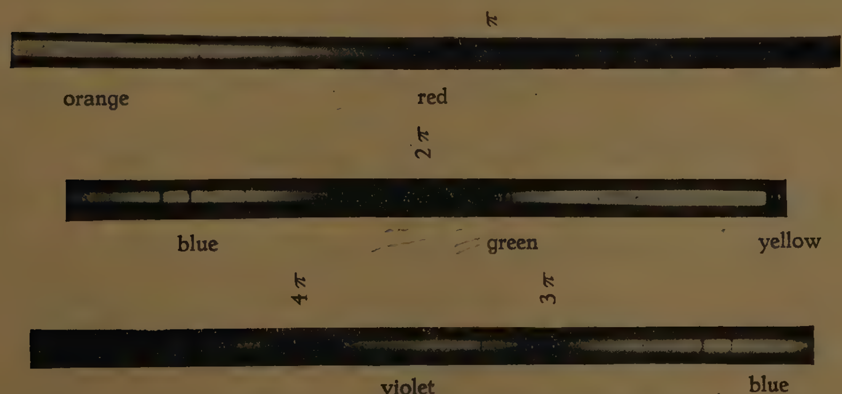

Fig. 4.

Tysonite, fluted spectrum in a magnetic field (actual size).
$H = 23$ kilogauss approx., thickness of crystal 1,67 mm. $T = 20^\circ$ K.

[1]) JEAN BECQUEREL, le Radium 4, 328, 1907.

crystal, becomes, after passing through the quarter wave plate, a difference in path between two rectilinear vibrations from which a displace-

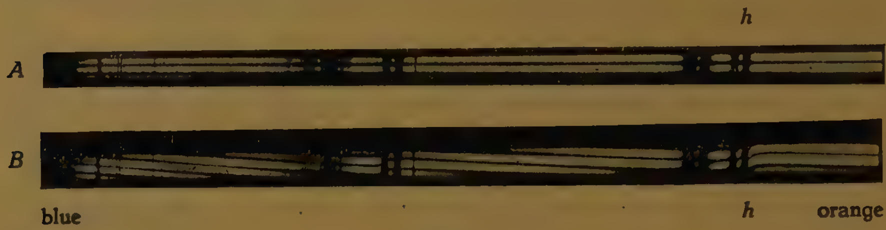

Fig. 5.

Magnetic rotatory power of tysonite at 4°.2 K.

Incident light rectilinearly polarised, plate of tysonite normal to the axis and 1.67 mm. thick, $^1/_4$ wave plates, Babinet compensator, nicol analiser, spectrum first order, actual size.

A. Central fringe of the compensator, without the magnetic field.

B. Fringes in a field of 23 kilogauss.

ment of the fringes of the compensator results [1]). A rotation through an angle π is transformed into a displacement equal to the distance l of two consecutive fringes, and a displacement d is equivalent to a rotation $\pi \frac{d}{l}$.

Fig. 5*A* shows the central fringe of the compensator without the magnetic field (At the blue end of the spectrum the next fringe can be seen). Fig. 5*B* shows the fringes in the field. The increasing inclination of the fringes shows clearly the rapid increase of the rotatory power with decrease of wave length. The disturbances produced by absorbtion bands sensitive to the magnetic field are also to be seen.

One of us has measured the magnetic rotatory power on the plates obtained this year at Leiden (20° K. and 4°.2 K.) as well as on the old plates obtained in 1910 in the physical laboratory of the Muséum at a temperature of 291° K. For the latter temperature the experiments were made with monochromatic light, — the mercury violet, green and blue lines. The method of fringes of the Babinet compensator was used. At the temperature of 291° K. visual measurements were made in the Muséum using the well known method of cut nicols, with line 5460.74 (a line from the mercury arc). These visual measurements confirm to some tenths of a degree those obtained by the method of fringes for the same wave length.

As plates obtained in fields of 8000 to 26000 gauss show that even at 4°.2 K. the magnetic rotation is proportional to the field (at least in the region without absorbtion bands), the magnetic rotatory power has been reduced (by simple proportion) to 10.000 gauss and a thickness of 1 mm. [2]). The following figures for 20° K. and 4°.2 K. represent the results of interpolations from a large-scale graph plotted from the

[1]) The fact that the plate is not exactly a quarter wave length for the whole spectrum, does not affect the displacement of the fringes.

[2]) We have assumed the proportionality with thickness.

measured values for a large number of wave lengths [1]) in the region least distorted by the absorbtion.

Magnetic rotation of tysonite of 1 mm. thickness and 10.000 gauss.			
λ	Rotation at 291° K.	Rotation at 20°.36 K.	Rotation at 4°.21 K.
3738.5	—	—	994°.3
3800	—	230°.9	941°.7
3850	—	221°.9	902°.0
3900	—	213°.0	865°.3
3958.5	—	—	825°.1
3985	—	199°.6	—
—	—	absorbtion bands	absorbtion bands
4015	—	195°.0	—
4021.6	—	—	783°.8
4046.6	13°.7	—	—
4100	—	182°.4	738°.3
4200	—	169°.6	686°.6
4253	—	164°.0	—
4256.7	—	—	660°.1
—	—	absorbtion bands	absorbtion bands
4300	—	159°.0	640°.2
4327.4	—	—	628°.8
4358.3	11°.0	—	—
4372	—	151°.8	—
—	—	absorbtion bands	absorbtion bands
4428	—	146°.4	—
4500	—	139°.6	—
4600	—	131°.2	—
4628	—	128°.8	—

1) The fringes were surveyed with the micrometer millimetre by millimetre and sometimes with smaller intervals, whilst each fixed point was read ten times. The total number of measurements required for the survey and for the determination of the wave lengths reached several thousand for each plate. The measuring, the plotting of the graphs and the numerical calculations require considerable time and, hence, we are as yet unable to give definite results concerning the other three crystals studied.

Magnetic rotation of tysonite of 1 mm. thickness and 10.000 gauss. *(Continued)*			
λ	Rotation at 291° K.	Rotation at 20°.36 K.	Rotation at 4°.21 K'
—	—	absorbtion bands	absorbtion bands
4728	—	121°.4	—
4766.7	—	—	481°.7
4800	—	116°.5	471°.6
4900	—	110°.6	445°.8
4950	—	107°.7	434°.3
5019.9	—	—	420°.2
—	—	absorbtion bands	absorbtion bands
5236.2	—	—	374°.8
5300	—	—	363°.7
5400	—	—	347°.2
5432	—	84°.6	—
5460.7	6°.4	—	—
5500	—	82°.1	331°.7
5600	—	78°.8	317°.4
5665.4	—	—	309°.2
—	—	absorbtion bands	absorbtion bands
5839.0	—	69°.9	—
5890(D_2)	—	68°.9	—
6000	—	66°.3	—
6100	—	64°.2	—
6210	—	61°.8	—
—	—	absorbtion bands	absorbtion bands
6262	—	60°.8	—
6300	—	60°.0	—
6391.2	—	—	228°.5
6400	—	57°.8	—
6500	—	55°.7	—
6600	—	53°.6	—
6657	—	52°.6	—

It must be noted here that the values given reduced to 1 mm. thickness and 10.000 gauss contain systematic errors resulting from the measurements of the plates and of the magnetic field, but these errors have no influence on the ratios of the rotations as the same plate and the same field have been used.

The most interesting question is the comparison of the ratio of the rotations at two different temperatures with the inverse ratio of the temperatures:

λ	4046.6 Å	4358.3	5460.7	
rot.$_{20^\circ.36\,K}$	$190^\circ.2$	$135^\circ.0$	$83^\circ.5$	
$\frac{\text{rot.}_{20^\circ.36\,K}}{\text{rot.}_{291^\circ\,K}}$	13.9	13.9	13.1	$\frac{291.0}{20.36}=14.29$

λ	3800 Å	4150	4850	5500	6391	
rot.$_{4^\circ.21\,K}$	$941.^\circ 1$	$711^\circ.7$	$458^\circ.2$	$331^\circ.7$	$228^\circ.5$	
$\frac{\text{rot.}_{4^\circ.21\,K}}{\text{rot.}_{20^\circ.36\,K}}$	4.08	4.05	4.04	4.04	3.94	$\frac{20.36}{4.21}=4.84$

From these figures it follows that the magnetic rotation increases slightly slower than $1/T$ between room temperature and 20° K. and very much slower when the temperature is lowered to 4° K. It is possible, perhaps, to suppose that the paramagnetic susceptibility of tysonite (neodymium and praseodymium) only follows the law of Curie after a correction for an anomaly, the value of which is otherwise very small, has been applied [1]).

The figures seem to indicate that the ratio of the rotations at two temperatures is not completely independent of the wave length as it decreases slowly as the wave length increases, but it is not certain that the accuracy of the measurements was enough to establish this result.

The curves in fig. 6 represent the rotatory power (the rotation in degrees as ordinate) as a function of the wave length at the temperatures 291°, 20°, and 4°.21 K.

The continuous portions of the lines correspond to those regions in which the numerous measurements were made, these regions being chosen outside the groups of absorbtion bands. At the extremities of the continuous portions an abnormal curvature is often obtained, due to the approach of absorbtion bands. The undisturbed portions are joined with dotted lines which would represent the rotation in the absence of the influence of selective absorbtion. On the curve corresponding to 4°.2 K. three isolated points are marked, two in the yellow and one in the red.

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[1]) Rapport Conseil de Physique Solvay, Brussels, April 1921, Leiden, Comm. Suppl. N^0. 44*a*.

These were determined from the position of the fringes between crossed nicols. The curve is dotted as no other points were determined in this

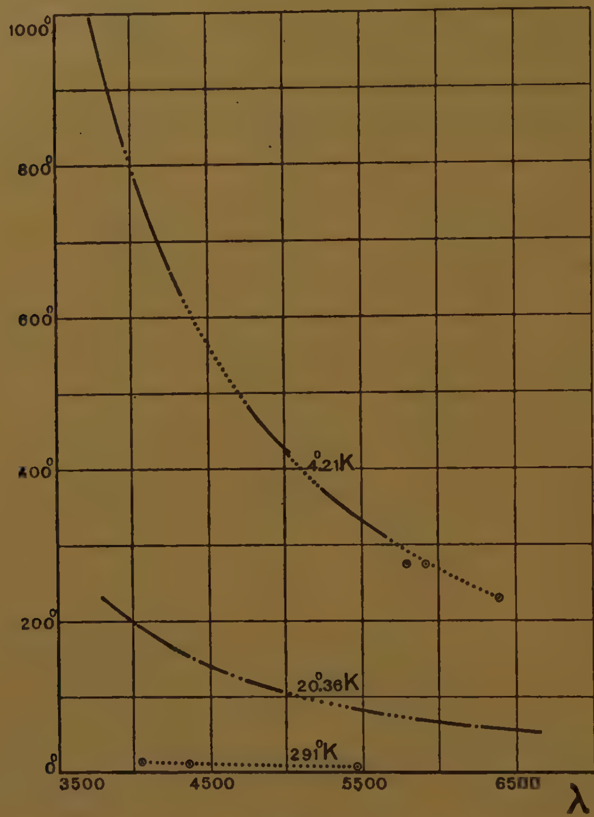

Fig. 6.

region. The two points in the yellow lie off the curve, they lie, in fact, in a region where the influence of the very intense absorbtion bands in the yellow is felt.

As was mentioned above, only three points were determined at 291° K., and these are joined with a dotted line.

For *parisite* we can, as yet, only indicate the order of magnitude. In round figures, the magnetic rotation is four times greater at 20° than at 80° K., and it is again increased fourfold when the temperature is lowered to 4°.2 K.

Bastnaesite also shows an increase of the same order as for tysonite and parisite. These three crystals all owe their paramagnetism to the same elements, neodymium and praseodymium.

The phenomena with *xenotime* (erbium) are far more complex, not only because of selective absorbtion bands very sensitive to a magnetic field, but also because of large regions of slight absorbtion spread through the whole spectrum, which must influence the magnetic rotation. The magnetic

rotatory power is much less than that of crystals containing neodymium and praseodymium. However it is still appreciable; for example at 4°.2 K.

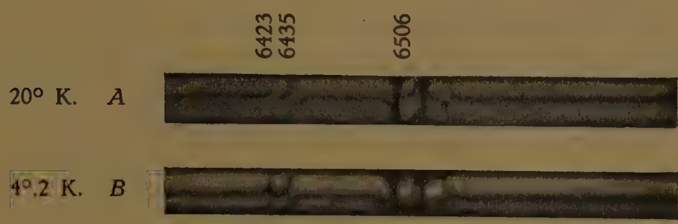

Fig. 7.

Xenotime. Variations of the magnetic rotatory power in the region of absorbtion bands sensitive to the magnetic field; group in the red, spectrum of the first order; field about 24 kilogauss, twice enlarged.

A. Temperature 20° K.
B. „ 4°.2 K.

with a plate 0.81 mms. thick and in a field of 26.17 kilogauss a rotation of 180° is obtained in the extreme violet (4060 Å.) and of 60° in the red (6800 Å.). It will be necessary to see if the rotation is, or is not, proportional to the field in the most transparent parts of the spectrum. It is possible that no proportionality exists owing to the influence of the absorbtion being felt throughout the spectrum.

Whilst for crystals containing neodymium and praseodymium the law of the rotatory dispersion is almost independent of the temperature, this is not the case with xenotime. The measurements actually made, although very incomplete, are enough to permit the statement that the ratios of the rotations, in the same field of 26.17 kilogauss, at 4°.1 and at 20°.36 K. are exactly equal to 2 from the extreme violet to the green (5000 Å.), becoming 2.2 for the yellow light of line D and greater than 2.3 in the red (6600).

There appear to exist two kinds of magnetic rotation of the plane of polarization arising from essentially different causes. One of these, generally in a positive direction, can be completely explained; it is the result of the ZEEMAN-effect on the absorbed rays, and its existence is apparent from the dispersion.

From our hypothesis, the other rotation should occur in paramagnetic bodies, be negative and result from a dissymmetry of the intensity in the absorbtion of opposed circular waves caused by orientation or distortion phenomena brought about by the field.

These two opposed effects should be superimposed in paramagnetic bodies, one or the other predominating. In connection with this one knows that the magnetic rotatory power of paramagnetic substances is generally negative, but is sometimes positive.

Histology. — *"On the development of the Purkinje-cells in connection with the problem of localisation in the cerebellar cortex."* By RUD. BERGMAN. (Communicated by Prof. J. BOEKE.)

(Communicated at the meeting of November 28, 1925).

In connection with the so very interesting researches of the last years concerning the localisation of the function(s) of the cerebellum, one unconsciously returns to search for a visible basis for them, for anatomical differences in the subdivision of the cerebellum.

The histological investigation of the cerebellum has now lead to the opinion that its structure repeats itself with the greatest monotony from fold to fold. Even in different kinds of animals one finds quite a uniformity of structure. Furthermore, between the different cells exist ways of communication which extend themselves in all possible directions (ESTABLE), and these are so extensive and numerous that this investigator does not find in these facts a reason to admit the hypothesis of a localisation. This intricacy cannot, however, be an argument against it, because in this confused net of wires it is quite possible that very small differences in the connections may exist which heretofore have escaped all observations. Besides, although it is naturally to be expected that to morphological different elements different functions are attributed, one must not take it for granted that to similar elements, a priori, the same functions are to be ascribed too.

A localisation in this sense that certain groups of muscles have their own projection-area in the cortex of the cerebellum is really not supported in the required exactitude by the course of the fibres. Indeed to name only the two most principal known ascending tracts, the one of the spino-cerebellar and the vestibular ways, these end in birds, according to different investigators, in fore- and hind part of the cerebellum, without making in doing so a difference between lateral and medial parts. Thence in connection also with what one finds in lower animals, it is sometimes concluded that these fore- and hind parts are phylogenetically the oldest parts of the cerebellum. The remainder has developed itself thereon as neo-cerebellum.

The physiological experiments, like the course of the fibres, has not been able to support in particular this conception of localisation although these give very important reasons therefore, as f.i. the connection between lobulus simplex and neckmuscles, between crus I with lobulus ansiformis and the muscles of the foremost homolateral extremity, between crus II with lobulus paramedianus and the muscles of the hindermost homolateral

extremity, demonstrated in mammals; herewith also the possible subdivision of centra for ab- and adduction (VAN RIJNBERK, THOMAS a.o.).

ARIENS KAPPERS thinks that in case the localisation does exist, it is to be expected in the fronto-caudal and not in the latero-lateral direction. He relies on the fact that the parallel fibres run in transversal direction and thus make in that direction an extensive connection between the different elements. These motives preserve in our mind their full value, notwithstanding the already named observations of ESTABLE concerning it, and notwithstanding the fact that there exist associative fibres between the laminae. Thence it may be declared that such associative fibres are very easy to follow directly from one lamina to the other with COX' method.

The intention of this short investigation is to verify by means of the COX' method if a difference may be shown in the development of the PURKINJE-cells of the different cerebellar folds during embryonal life.

A difference in the development in different places of the cerebellum in the human embryo is already described by VAN VALKENBURG.

As material use was made of chicken embryos fixed during a certain period in COX' liquid, from the 14th breeding day to and including the third day after the hatching of the chick.

In the first place for this investigation it was necessary to follow the different forms of development of the PURKINJE-cells as accurately as possible, as great and brusque differences between its development in the different folds may not be expected. The histogenesis of the cerebellar cortex was described in 1897 a.o. by ATHIAS in a very interesting study. He made use of the GOLGI method, and had at his disposal young dogs, newly born cats and embryos of caviae. All these animals, with the exception of the caviae, have very imperfectly developed PURKINJE-cells when they are born, and one finds in the same section all kind of stadia of development, as in confusion through one another.

On the contrary in the chick, the cells of PURKINJE are already more or less unfolded, the first day after the hatching. One finds them in the chicken embryo of nearly 15 days breeding like they, according to the drawings of ATHIAS, appear in the newly born rabbit. Quite different developmental forms in the same section in the chicken are found principally on or about the 18th and 19th breeding day. Earlier or later the cells have a more regular appearance.

ATHIAS explains the way of development of the PURKINJE-cells as follows. In recently born cats f.i. they are ovoid bodies, quite large, very irregular with many and varying branches. The axis-cylinder is easily to be seen, and sends out side branches. Through resorption the thorny projections of the cells disappear and a thick stem appears on the top. Still later the stem begins to flatten and to extend itself in several branches. The earlier small branches are still more resorbed. A definite age for each of the shapes is not be given, because they appear so very mixed.

We could follow the detailed course of development as follows. In

the youngest stadium that we have seen (14th day of breeding), there are only irregular formed cellbodies, quite large in comparison to the other elements. From these cellbodies many thin, mostly unbranched shoots radiate out in all different directions and a long thin axis-cylinder runs to the white matter (a, 1st cell in the figure). Thereupon a few of these dendrons become somewhat thicker than the others, and they start to branch out (b, 2d cell). It seems then also that the cellbody increases in size (c, 3d cell). Next this is somewhat more strongly expressed and so it seems now as if the protoplasma of the cellbody bulges out into the thickening dendrons (d, 4th cell). One or two of the dendrons towards the cortex surface then become distinctly thicker than the rest, whereas cellbody and branches are very irregular in shape. Somewhat further there is really only one thick dendron left, but still surrounded by many thinner ones, who originate from the cellbody and from the principal trunk, (e, 5th cell). Thereupon the cell seems once more to take the aspect of a younger period, irregular shape with a thick projecting lump. But now the cellbody clearly becomes larger and almost all of the thin dendrons are no more to be found, retracted or resorbed (f, 6th and 7th cells).

From now on the cell of PURKINJE starts to develop itself clearly in the direction of its definite shape, the cellbody becomes more or less regularly oval but still with many knobs and indentations. A thick dendron runs to the surface of the cortex and ramifies into a small end-tuft. In further stadia the most remarkable is certainly the increasing ramification of the end-tuft (g, 7th and 8th cell). But gradually the irregular points on the cellbodies disappear (h, 9th cell). Still later the chief branches of the cell seem to intend to expand further from the stem rather than to ramifie more profusely. This stadium with its rarefied, bald and angular branches reminds one of the shapes of the cells of PURKINJE in the lower animals, in the pike f.i. (i, 10th cell). Once the cell is so far, all the small branches produce new sidebranches and this repeats itself continually (k, 11th and 12th cell) till in the full grown form a dense entanglement of twisted branches arises (l, 13th cell). All these different forms are indicated here with a letter.

The axis-cylinder usually has side-branches. ATHIAS found in his mammals sometimes a neuron with as much as eight. In chickenembryos and chicks, we always found only a few. The so called "boutons dendritiques terminaux" were never seen by us in this research. Neither was any connection found between the dendrons and the meningeal vessels (KAPPERS).

A difference between the medial and lateral parts of the cerebellum is also not to be seen. The development seems to be as far in the medial as in the lateral sections. Besides INGVAR says "Sämtliche Autoren sind darüber einig dasz das Vogelcerebellum nur aus Vermis besteht". This surely also is no inducement to seek localisation in a transversal direction. We remember too that ARIENS KAPPERS does not think a lateral localisation

Fig. 1.

very probable because of the extensive intercellular communications in that direction.

The development of the folds themselves takes a tolerably simple course. MESDAG describes in the chickenembryo the appearance of cerebellar folds on the 9th breeding day, which folds are about ten in number on the 13th breeding day. INGVAR sees in the chickenembryo of 10½ days three lobes. The lobus anterior is divided in four lobules, the lobus medius in two, the lobus posterior in three. On the 16th day the fourth lobulus of the lobus anterior, divides itself into two sublobules. This remains so up to the 19th day and mainly similar in adult animals. The lobus medius according to INGVAR has remained somewhat behindhand in development in relation to the other two, it also shows most of the changes in the phylogenetic series. The division of the cerebellum in lobes and lobules is however subjected to small individual changes f.i. in the cerebellum of a chicken embryo of 20 breeding days we found the first lobule of the middle lobe divided into only two sublobules, while one can observe the division into three sublobules already on the 17th day. On the 17th day, the fourth lobule of the anterior lobe divides itself into three sublobules and the first lobule of the posterior lobe into two. The two lobules of the middle lobe have divided themselves too, the first into three, the second into two sublobules. One also finds then a few subdivisions on the sides of the great folds, but their invasion by the white matter is very inconstant, wherefore it is better not to give them too much notice.

ATHIAS finds in his animals that the least developed cells are to be found in the deeper laminae, at the bottom of the grooves and in the deepest

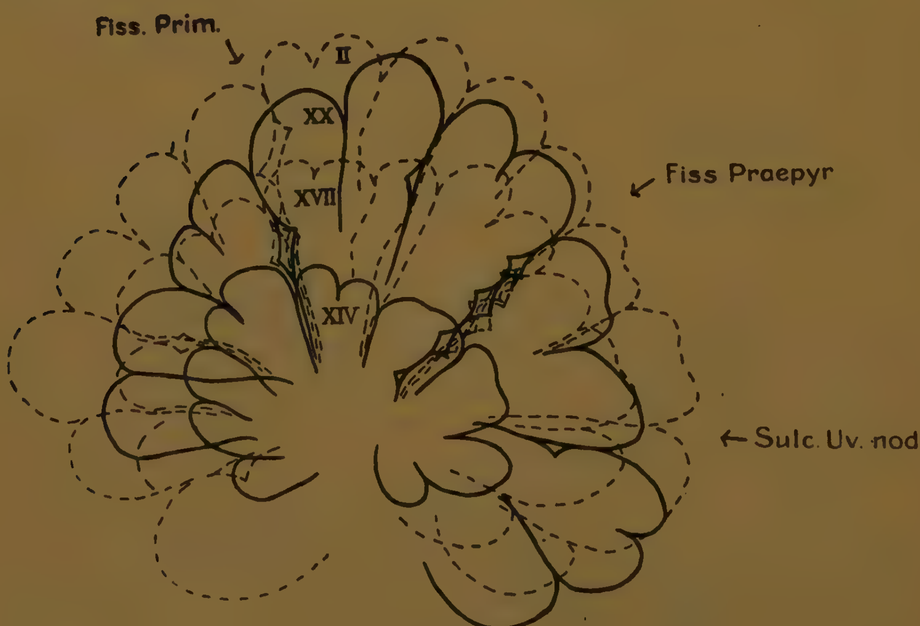

Fig. 2.

parts of the laminae, that means everywhere where the superficial granular layer is thickest. KOLLIKER also mentions that the highest developed PURKINJE-cells are to be found at the top of the folds.

In the chickenembryos we always found, with the COX' impregnation method, the more developed cells at the bottom of the grooves, while the upper parts of the folds showed less developed cells, and also a smaller number of impregnated cells. Furthermore all large laminae reach the surface here, so that there is no cause to distinguish "lamelles profondes" from others.

Generally speaking, one can say that in a certain fold, a certain developmental type is rather sharply accentuated. One great difficulty here is naturally to avoid a too haphazard judgment. More is the pity, we know nothing about the theory of impregnation, so that from a certain number of impregnated cells per fold absolutely no conclusions can be deduced.

At last it seemed the most accurate way to indicate the folds by means of the letter of the developmental type of PURKINJE-cell which was predominant in it.

The folds themselves are divided according to INGVAR, and indicated by the names which this writer uses according to BOLK, e.g. a lobus anterior with four lobules, a lobus medius with two lobules and a lobus posterior with three lobules; for boundaries the fissura primaria and the fissura praepyramidalis.

So it appeared that on the 14th breeding day there was really no difference. One sees the cells as in the first four drawings corresponding to the letters a, b, c. On the 15th breeding day there is no much clearer difference. One sees the cells mostly like those of the fourth and fifth drawings, letters d, e. Through technical errors the sections of the 16th and 21th days got lost. In the 18th, 19th, 20th days however it becomes clear that the middle lobe shows a less developed type of cell (7th up to 9th cells of figure 1, letters g, h) than the two other lobes (9th up to 11th cells, letters h, k). Moreover it appears that the anterior and posterior lobes are equivalent in this respect.

Directly after the hatching of the chick one sees adult PURKINJE-cells nearly everywhere. If one plots the development per lobe and per breeding day on a curve, then it becomes still more evident. (Fig. 3). The dotted lines represent here the degree of development of the anterior and posterior lobus, the drawn line that of the middle lob. The vertical distance between both lines is very small for the first days and nought in the days after hatching, on the contrary clear on the 18th, 19th, 20th days.

If we want to test this fact on other data, it firstly does not seem very well possible to us to seek any connection between these anatomical differences and the possible functional differentiation that would agree with the projection area of certain muscle groups. On the other side we read in ARIENS KAPPERS that the associative function principally belongs to the lobus medius, that this lobe serves for the harmonical working

together of the different parts of the body. INGVAR informs us that the spino-cerebellar fibre systems end in the lobus anterior and the lobus posterior; and that the direct vestibular fibres to the cerebellum go nearly all to the cortex of nodule, uvula, flocculus and to the anterior part of the lobus anterior. He therefore considers the anterior and posterior lobe to be

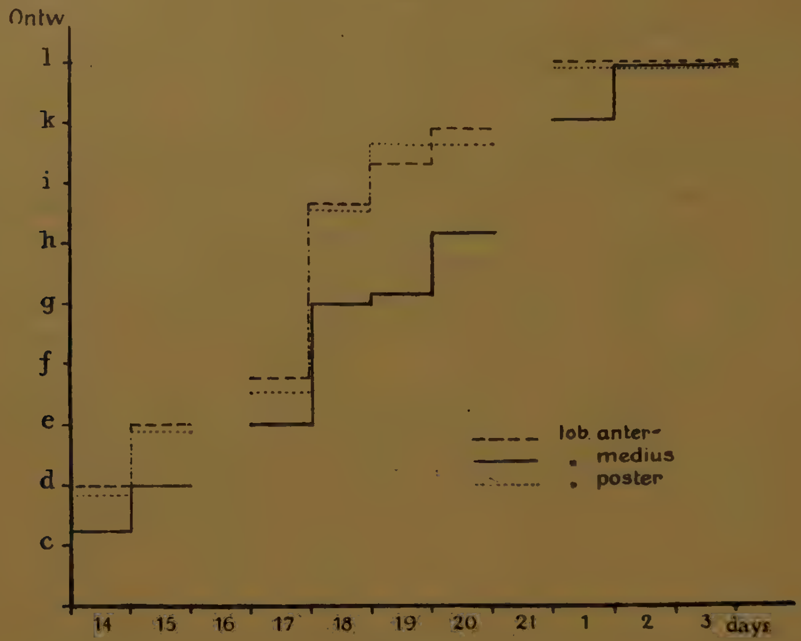

Fig. 3.

phylogenetically older than the middle lobe. It is in accordance herewith that we could differentiate the development of the PURKINJE-cells in the ontogenesis, so that this development in the phylogenetically oldest parts is most advanced, and first completed.

That there is not always a clear differentation into palaeo- and neo-cerebellum, during the embryonal period, is comprehensible when we remember what WINKLER writes on it: "The neocerebellum is partly growing by intussusception between the palaeo-cerebellum, and partly by apposition upon the older part...... distinct borders between them do not exist." As the chick can move fully, walk, peck etc. directly upon hatching, it will not astound any one that the lobus medius then has fully developed PURKINJE-cells, and in this respect is fully the equal of the other lobus.

The phylogenetic explanation is, however, not the only one that fits in here: according to ARIENS KAPPERS the dendrons have a stimulopetal growth. Now the centripetal systems that are already clearly present in embryonal life, end in the anterior and posterior lobus (spino-cerebellar and vestibular tracts, cfr. supra). The associative functions become accentuated much later. For this reason too it seems comprehensible to us that the middle lobe develops more slowly than the others.

As a curiosity it can be mentioned that in an embryo of 18 days an inverted cell of PURKINJE was found. This cell lay in its normal situation, may be a little bit too much towards the surface of the cortex. The dendrons run principally in the direction of the white matter, many short thin branches protrude from the cellbody. The neuron arises laterally out of the cellbody and then bends towards the white substance (Fig. 4).

Fig. 4.

No importance can be attached to such an isolated cell. Possibly it is one of the elements described by CAJAL as "displaced cells of PURKINJE". In this case it would have remained alive because of its still retaining its normal connections with other cells; it has then however not taken the star-shape, but has remained true to its original shape (ESTABLE).

Concerning the technics we can be short. COX described in 1891 his excellent impregnation method. He mentions thereby however that one is compelled to use the technics of frozen sections. Imbedding in paraffin proved impossible, and in celloidin only possible with great disadvantages, as the treatment with alcohol would harm the impregnation.

COX' method has the advantage that it is simple, succeeds with great surity and gives sharp images with relatively few deposits.

Now to get serial sections it was desirable to use paraffinimbedding instead of frozen sections. Experiments to imbed in paraffin of 58° with the usual method via alcohol and xylol failed totally. The frail tissue continually broke into small shreds. Successively the hard paraffin was replaced by soft (50°), the incubator brought to 51°. Instead of xylol came chloroform and cedar-oil was interposed between absolute alcohol and chloroform.

The remaining in COX' liquid for months on end makes the tissue extraordinary weak and vulnerable. It is already enough to destroy much when

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one simply seizes it with a pincet. Therefore it is advisable to use a small piece of dressing-gauze stretched over a small glass ring. In these small nets one transfers the pieces from liquid to liquid. This has to be done as quickly as possible f.i. in 24 hours in this manner : first the pieces some hours in repeatedly renewed distilled water, then half an hour in the alcohols of 50 %, 70 %, 96 %, and one and a half hour in absolute alcohol; therefrom in cedaroil, wherein it remains overnight. Next one brings them in cedaroil with chloroform a few hours, then four hours in chloroform-paraffin at 37° and lastly half an hour in paraffin I and II at 51°, and then imbedding.

With this working method one certainly succeeds in obtaining well embedded pieces. They are cut most easily on the sliding-microtome. One can then go to ninety mu. Naturally the sections curl and break then very easily. One avoids this by keeping the tip of the finger for a moment on the piece and leaving it there while the section is cut. One must hereby avoid pressing the section onto the knife : it is not the pressure but the warmth of the finger which is effective here.

Lastly the sections must be glued onto the slide. We use for that purpose a thin layer of albumin-glycerine smeared on an absolutely fatless slide. The section is pressed on this with the finger, while one is careful not to let airbubbles get between the slide and the section. One lets the slide dry like this for half a day at ordinary temperature. Stretching and fixing by means of heat is not advisable, it does not succeed and the sections crumble away again. The paraffin is removed out of the sections by means of xylol. Via the alcohols they are brought in water, and then they come a few hours in a 5 % solution of sodiumcarbonate. If it remains longer it only gets a little whiter as the yellow colour of the bichromate gets lost. After the treatment with alcali the sections are again washed and taken through the series of alcohol to xylol. One removes the xylol from the sides of the slide, covers with thick xylol-canadabalsam and puts them in a dustless place to dry.

A coverslip can not be used according to COX as the stained cells then break up into small granules after a few weeks. This was also shown in this research.

Lastly a disadvantage must be mentioned. In some sections there forms after 6—7 weeks a precipitate of mercuric chlorid needles. What causes this and how it can be prevented has not become clear to us. Moreover in some sections the cells break up into granules even without a coverslip and kept in the dark, even after having remained allright for over a year.

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Anatomy. — *"On the temporary Presence of the primary Mouth-opening in the Larva of Amphioxus, and the Occurrence of three postoral Papillae, which are probably homologous with those of the Larva of Ascidians."* By J. W. VAN WIJHE.

(Communicated at the meeting of November 28, 1925).

The dorsal organs of the Amphioxus-larva, especially the chorda, the myotomes and the nervous system exhibit also in the adult animal so many primitive features that in comparative morphology they constitute the basis, on which our knowledge of the skeletal-, muscular-, and nervous system is founded.

By the even segmentation of its muscles, and the (dorsal as well as ventral) peripheral nerves Amphioxus affords living evidence of the primary segmentation of the head of the higher animals, though it may be ever so much involved in obscurity during their development.

Leaving details out of consideration morphologists are fairly agreed as to the significance of the dorsal organs of the larva of Amphioxus.

This accordance is far to seek with respect to the ventral organs in the anterior part of the body, as far as the posterior border of the pharynx.

The reason is that in this region of the body organs pass across to the right side, and conversely also parts belonging to the right side can be found on the left area.

It is not surprising, therefore, that unpaired morphologically median organs will appear to have shifted to the left area, whereas of a paired organ the antimere can be observed for some time in the topographical (apparent) median plane.

A similar displacement from left to right, and from right to left does not take place with the abovenamed *dorsal* organs. However, in the myotomes and peripheral nerves of the right side we do observe, relative to those of the left side, a slight move caudad.

Among the *ventral* organs a similar slight move is also seen in the gill-slits of the right side relative to those of the left. A much more pronounced displacement can be observed of the posterior portion of the mouth-opening during the larval growth of the Amphioxus. When this opening has reached its maximum at the outset of the metamorphosis, its posterior portion is found opposite to the fifth gill-cleft, and the anterior part of the left postoral papilla goes on pari passu with it.

These phenomena also, but especially the passage of organs of the one side of the body to the opposite side were ever, and are still confusing.

To possess some knowledge of the morphologically ventral medianline is,

therefore, of prime importance for the morphological significance of the organs in the anterior part of the body of the Amphioxus larva; we do not mean only of the ventral medianline of the skin, but also of that of the intestine.

In the higher animals both lines lie in the region of the pharynx in the topographical median plane, which is at the same time morphological median plane. The two lines run parallel and are consequently similar in shape.

In the larva of Amphioxus on the contrary the two lines fall outside the topographical median plane, which is at the same time the morphological median plane only for the above-named *dorsal* organs. Both lines also follow their own course and differ largely as to shape.

Before indicating their course it will be found desirable first of all to describe the occurrence of three epidermal papillae in the Amphioxus larva. Of these three the anterior one is unpaired, while the other two form a pair.

Larva with a single open gill-slit:

This slit is the foremost of the left row of gill-slits which occur in the period of larval growth orderly arranged in a caudal direction. At the beginning of the metamorphosis they amount not to 14 or 15, as is generally believed, but to 18 and probably to 19 [1]), as I find.

The gill-cleft of our larva disappears during the metamorphosis and of its antimere on the right side of the body even the rudiments are lacking.

But though, as to its function, it is the first in the row during the larval growth, morphologically it is the second, as it is preceded by a paired slit that has lost the gill-function and the left antimere of which is represented by the mouth-aperture. Its right antimere is the club-shaped gland. This gland has retained and developed the pouch-shape, which is originally peculiar to all gill-slits (gill-pouches). The intestinal orifice of the club-shaped gland lies high up on the right side, not far below the chorda. The skin-orifice is found on the *left* side of the body, where it must have shifted. This place is of some significance for the localization of the morphological median line of the skin in this part of the body. The skin-orifice lies on the posterior margin of the anterior unpaired epidermal papilla, not far below the pointed anterior termination of the mouth opening and slightly more directed towards the rostrum.

The wall of the clubshaped gland consists of three kinds of cells, so that

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1) The metamorphosis starts with the appearance of the anterior 6—9 gill-pouches on the right, as entoderm-thickenings in the right boundary fold of the intestine along the truncus arteriosus. This phenomenon is attended with the occurrence of the rudiment of 1 or 2 cirri (the hindmost of the later oral skeleton) and the incipient formation of the atrium by the concrescence of the right-, and the left ventral finfold.

Willey (1891) has discovered that during the metamorphosis the left gill-slits are reduced to 8 or 9 by the disappearance of the posterior slits. while also the first slit perishes.

three divisions can be distinguished in it; 1^0. a proximal, long and broad secernent portion with high granular cells; 2^0. a long narrow duct, with very flat cells, and 3°. a small piece inserted between the other two divisions. It has the shape of a ring, from which a piece has been cut. This opening is at the back of the ring, so that here the secernent cells and those of the efferent tube are contiguous.

From a morphological point of view this small central division (see Fig. 1) is quite interesting, because its cells cannot be differentiated from those of the epithelium of the gill-slits. Each cell is provided with a long flagellum, extending far into the efferent tube, but not projecting from the fine skin-orifice.

The secernent-, and the central-divisions of the clubshaped gland are undoubtedly products of the entoderm, but the efferent tube is presumably an involution of the ectoderm. A similar but much shorter ectodermal involution is also found at the skin-orifice of the true gill-clefts.

In the vicinity of the mouth our larva displays three papillae, made up of enlarged ectodermal cells. The front papilla is unpaired; it lies on the left side of the body, right in front of the mouth. The other two are paired. They are located behind the mouth. I shall call them the right, and the left postoral papillae. The position of the left papilla is apparently median (i. e. in the topographical (apparent) median plane). It is on its way backward, for it is already advanced below the first gill-slit, while in an earlier embryonal stage KOWALEVSKY (1867, Fig. 24) figured it in the region of the clubshaped gland.

Its position enables us to recognize it, when the larva turns the left side to the observer, as well as when it presents the right side. It is composed only of one longitudinal row of about 7 cells.

Its antimere, the right papilla, can be seen only when the larva turns its right surface up. At a high focus of the microscope it can be recognized in the region of the clubshaped gland under the posterior half of the vaguely visible mouth. It does not shift, but is soon seen to grow for some distance in a rostral direction and much farther caudad.

The mouth has already elongated caudally and previously lay before the spot now occupied by the papilla. This spot on the right surface of the body is found in the same region where in an earlier stage also the left papilla lay in the topographical median plane, according to KOWALEVSKY's figure, alluded to before.

These three papillae functionate in the larval stage of development, but perish even as the clubshaped gland during the metamorphosis. In my preparations they secrete a substance and are to be considered as cutaneous glands.

The anterior unpaired papilla is situated, as already stated, right in front of the mouth. Its upper margin borders on the orifice of the pre-oral organ (in which HATSCHEK's groove), and at its posterior margin the fine cutaneous orifice of the clubshaped gland can be observed under the anterior

part of the mouth. The papilla retains this position all the time of its existence.

It is approximately circular and is formed by a single layer of enlarged epidermal cells, each provided with a long flagellum. On the outside it is covered by a layer of flat epidermal cells. This covering possesses one large or several small perforations for the passage of the flagella. The secretion of the papilla clots inside the covering layer, during the fixation of the larvae, into one clump, in which the flagellate threads appear as boundaries of palissadeshaped cells. When now the free projecting part of those threads has got lost, which may happen during the fixation, we might believe that GOODRICH (1917, Fig. 7, 8, 9, *p o s*), was right in calling the papilla a sense organ.

In the larva with a single gill-slit it is by far the largest of the three papillae. Hitherto it was generally believed to be the only papilla in the vicinity of the mouth, for its discoverer, HATSCHEK (1881, p. 80) mistook it for the one already described by KOWALEVSKY (1867). HATSCHEK says of this papilla in the live larva; "die Geisslen derselben schlagen mundwärts", so it will have to convey to the mouth not only its own secretion, but also that of the clubshaped gland and of the groove of HATSCHEK.

These secretion-products will come into play in the process of adhesion and transport of food-particles.

Before long the right and the left papilla grow markedly in a caudal direction along the long axis of the larva. Now when in the later stages the right, and the left finfold have made their appearance, on either side of the body the ipsolateral papilla advances forward on the finfold in situ [1]). It then forms in the epidermis of that fold a longitudinal cell-band with strikingly large, round cells, that were figured by LANKESTER and WILLEY as early as 1890.

I never see the band extend the whole length of the finfold. It does not reach the region of the posterior gill-slits and accordingly is never found in the portion of the fold that is situated behind the pharynx.

MAC-BRIDE (1898) has no doubt seen the right papilla in the young larva, but he is mistaken in considering it as the rudiment of the finfold, as also LANKESTER and WILLEY did. He says (l. c. p. 606) : "the first recognisable trace of the future fold on the right side is an epithelial thickening in the anterior region of the pharynx. This thickening...... is recognisable even at the end of the embryonic period."

However, the papilla differs organically from the finfold. It appears very much earlier and its prolongation on the fold is a secondary phenomenon.

In a larva with 3 gill-pouches the posterior end of the right papilla has

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[1]) It is desirable not to speak of *finfold* before an excrescence of the mesoderm (of the somatopleura) has appeared in it.

reached the anterior margin of the 1st gill-cleft. The *left* papilla now lies beneath the 2 gill-pouch.

In a larva with 6 gill-pouches there is not yet a finfold. The anterior termination of the right papilla has grown up to the base of the snout, where it is found also in older larvae during their period of growth. Its posterior border reaches as far as the posterior border of the first gill-slit, which it overhangs.

The *left* papilla lies beneath the 4th gill-slit still in the topographical median plane and consists of a row of about 14 cells extending longitudinally.

The right finfold has appeared in a larva with 10 gill-pouches. It is still short and extends from the 1st to the 4th gill-pouch. Its anterior termination at the posterior border of the first gill-slit, already bears the posterior end of the *right* papilla. The *left* papilla row lies beneath the 5th gill-slit.

In larvae with 14 to 18 gill-pouches every papilla has established itself on the finfold of its own side and grows further in caudal direction, forming on that fold a longitudinal cell-band. [1])

GIBSON (1910) also found the cell-bands on the finfolds of Amphioxides and described them (l. c. p. 228—229). He considered them to be sense-organs homologous with the lateral organs of fishes. But he could not find a nerve.

In the larva of Amphioxus the large round cells do not resemble sense-organ cells but mucous cells. I see on the surface of the cell-band a coating of flat cells with a pore for every large cell. From these pores mucus can be seen to be secreted (the term mucus being taken in the most general meaning of a somewhat viscous substance).

The mucus-secretion, however, seems to occur only at long intervals, for several larvae have to be cut, before it can be identified. It may be also that the mucus gets lost in the treatment (see later on). Cilia or flagella are absolutely lacking, which constitutes the difference between the paired and the unpaired papilla, while also the secretion-product of the unpaired papilla will undoubtedly be of a different chemical composition from that of the cell-bands.

It is interesting to read in this connection the description given by KOWALEVSKY (1867 p. 7) of the (left) papilla, which was discovered by him, but which later authors could not identify any more. He found it in an embryonal stage, in which the mouth has just broken through as a small circular opening. In fig. 24 (l.c.) it consists of two somewhat enlarged successive cells, each with a large appendix projecting outwardly. His description runs as follows:

"An der unteren Seite unweit vom Munde bilden sich zwei kleine Warzen, auf welchen man zwei lange, längsgestreifte Tastfäden findet; bei der Behandlung mit Essigsäure ergiebt es sich, dass diese Tasthaare aus zusammengeschmolzenen langen Cilien bestehen."

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[1]) In these larvae the anterior termination of the left papilla is as a rule found in the region of the 6 gill-slit.

In my judgment these apparent tactile cilia are composed of "mucus", which generally gets lost. This accounts for the fact that among my numerous preparations of larvae with one gill-slit I could recognize only once a long thread at the papilla; and that it has escaped the notice of the observers after 1867, also on account of its smallness.

Fig. 1

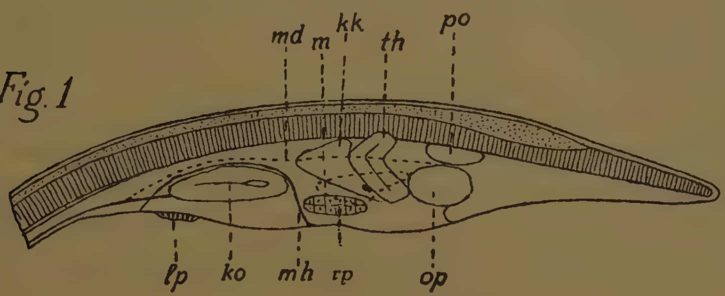

Fig. 2

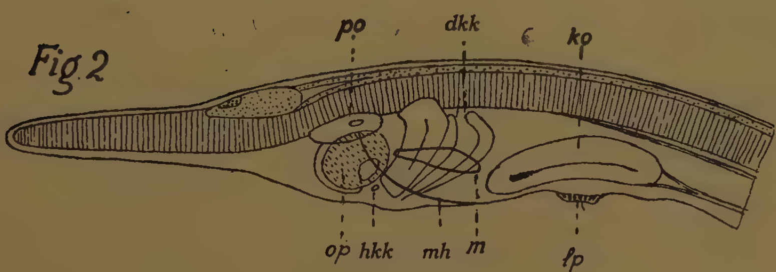

Fig. 1 en 2. Amphioxuslarvae with one gill-slit.

Fig. 1, a larva seen from the right side of the body, with some organs of the left side, looming through at a deep focus of the microscope.

Fig. 2, another larva seen from the left side, with some looming organs of the right side. *dkk* intestinal orifice of the clubshaped gland; *hkk* its cutaneous orifice; *kk* the gland itself; in fig. 1 its central division is represented as a small black spot; *ko* first gill-pouch; *lp* left papilla; *m* mouth; *md* ventral median line of the intestine; *mh* ventral median line of the skin; *op* unpaired papilla; *po* preoral organ; *rp* right papilla; *th* thyroid.

We are now in a position to establish more accurately the peculiar course of the morphologically ventral median line *in the skin* of the larva with one gill-slit.

With a slight deviation at the anal opening this line coincides with the topographical median-line of the tail and the larger part of the trunk behind the gill-slit. A little way behind this slit it bends dorsally round to the right side, to move anteriorly across the slit.

At the anterior margin of the slit it must again bend ventrally (Fig. 1 *mh*) in order to pass between the right and the left papilla. It now reaches again the topographical median-plane to continue on the *right-side* of the body (Fig. 2). Two places can be established where it has to pass: 1°. between the mouth and the cutaneous-orifice of the clubshaped gland;

2°. the unpaired papilla which is destitute of an antimere and consequently must be morphologically a median organ. In this way the line reaches the preoral organ, it does not matter to us how it runs farther forward [1]).

When tracing the line from this place backwards it follows a spiral course which begins at the preoral organ on the left side, passes between the mouth and the skin-orifice of the clubshaped gland, and then continues on the right side some way beyond the gill-slit. After this spiral course it bends round ventrad behind the slit, and advances caudad in the topographical median-line.

The shape of this line has a relation to the spiral movement that the larva presumably makes in swimming along, at the same time turning to the left [2]).

As the larva develops, the form of the line changes only at the back of the gill-intestine. As known, here a new left gill-pouch arises every time topographically medianly.

The morphological median-line must then turn dorsally on the right side of the body behind each new gill-pouch and subsequently overlap anteriorly the row of the gill-slits.

The course of the morphologically ventral median-line of the *intestine* is simpler than that of the skin. In the region between anus and gill-intestine, it exhibits nothing particular just as the skin-line. Here the topographical and morphological median-plane coincide and the median-line of the intestine is indicated by the vena subintestinalis, which in some places is split into two or more venae.

At the back of the gill-intestine this vein bends dorsally along the last

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1) Different opinions will be entertained concerning the further course of this line according as the preoral organ and the ventral coelomic vesicle of the snout are, or are not considered as antimeres.

I have advocated the second view, but the first has been generally received. In this connection it would import us to know whether the (left) preoral muscle is innervated by a left or by a right (ventral) nerve (n. oculomotorius).

When the muscle is innervated by a *left* nerve, it would lend support to my conception. The coelomic vesicle of the snout and the preoral organ (right- and left entoderm-sac of HATSCHEK) are then, in the embryo, only apparently antimeres, but are lying morphologically median, the one before the other, just as in the later larva. Then the morphological ventral median line in our larva with one gill-slit, bends from the opening of the pre-oral organ abruptly ventrad towards the topographical median line, with which it nearly coincides and runs to the point of the snout.

If, however, the preoral muscle is innervated by a *right* nerve (which in this case has to cross the inferior side of the chorda) the more generally adopted view will be the right one. Then the morphological median line of the skin runs from the primary mouth-opening (see below) between the two "entoderm-sacs" in a dorsal direction as far as the level of the chorda. From this point it continues on this level, ever keeping on the left side of the body, towards the extremity of the snout.

2) This movement, discovered by HATSCHEK (1881, p. 37) in the embryonal stage, was also noticed by FRANZ (1924, p. 6) in the adult animal. In swimming along this animal most often (not always) turns from right to left. This form of movement is called by FRANZ "Rechtsrotation", a misleading term. In the metamorphosed animal the movement is brought on by muscular contraction, in the embryo by the sweeping of the flagellae.

gill-pouch, as truncus arteriosus. The truncus [1]) then passes on the right side of the gut anteriorly across the intestinal openings of the row of gill-slits.

It can be traced here as far as the posterior margin of the clubshaped gland, where it ramifies into a number of fine branches (this ramification begins as a rule already before it reaches that posterior margin).

In the gill region the morphologically ventral median line of the intestine behaves similarly to that of the skin.

Both lines run on the right side of the body above the row of gill-slits. But towards the rostrum there is an end of all analogy. Here there are two spots to establish the course of the intestinal line: 1⁰. the place where the right, and the left arm of the thyroid border upon each other; 2⁰. the place of the primary mouth-opening, which we shall discuss on a later page.

When elongating the line in the direction of the rostrum along these spots (Fig. 1 *m d*) it will be seen to keep on the right side of the body, with the exception of a slight curvature at the extreme anterior portion of the intestine tending to reach the place of the primary mouth opening.

Since 1893 I have advocated the conception that the mouth and the clubshaped gland of the Amphioxus larva must represent the first pair of gill-pouches, homologous with that of the larva of Ascidians [2]). But then in the phylogeny of Amphioxus there must have existed in front of this pair a primary mouth-opening. This opening I supposed to be (not without hesitation, but there was no alternative) the opening of the preoral organ, although this organ has been severed from the intestine already in an earlier embryonal stage.

Nearly a twelve mouth ago, however, I found in a larva, *of the growth period*, with 15 gill-slits, a fine perforation of the intestine on the boundary between the unpaired papilla and the outlet of the preoral organ. It gives entrance into a duct, which widens like a funnel towards the lumen in the anterior part of the intestine. This duct is filled with a slimy mass, in which flagella are distinguishable, directed towards the intestinal lumen. The slime has most likely been derived from the preoral organ.

In the longitudinal section of the duct (in a series of transverse sections of the larva) its perforation had also been cut through, which is about the size of that of the clubshaped gland. The skin-perforation of this gland is of about the size of a cell-nucleus of the surrounding tissue.

Now I could also identify the opening of the duct in preparations, in which the duct had been cut obliquely; still, only in a limited number of stages, viz. in larvae of the *growth-period* with 12 to 15 gill-slits. It

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1) On transverse sections the truncus arteriosus lies on the inferior margin of the right boundary fold of the intestine.

2) BALFOUR (1881, p. 6) already reports that some workers suspected that the mouth of the Amphioxus larva was a gill-slit.

was lacking in larvae with 16 and 18 slits, also in larvae of the period of the metamorphosis.

Whether the opening exists already in younger larvae than those with 12 slits, I could not well make out. In larvae with a single gill-slit it was still closed at the indicated place, and according to GOODRICH's (1917, fig. 7, 8, 9) figures this is likewise the case in larvae with only few gill-slits.

In accordance with its position at the most anterior part of the intestine in the morphological median line of the skin, the opening under consideration must be the postulated primary mouth of Amphioxus.

It must be homologous with the mouth of the higher animals, as well as with that of the Tunicata, and not only the paired papilla, but also the unpaired lie morphologically postoral.

The unpaired papilla is situated in the mandibular region ; I have, therefore, termed it the *mandibular papilla* in an earlier paper.

The Amphioxus larva does not lend support to the hypothesis that the "preoral intestine" of the embryos of the higher animals should be of a particular, morphological significance, unless we understand by it e.g. the rudiment of the adhesive organ of the larvae of Ganoids, which may be homologized to the preoral organ of Amphioxus.

But the Ascidians are on account of their embryonal development much more closely related to Amphioxus. This relationship is still noticeable in the larva of Amphioxus with a single gill-slit (cf. VAN WIJHE 1914).

The position of its three papillae is postoral [1]) relative to the place of the primary mouth-opening, just as the three papillae of the larva of the Ascidians [2]), according to KOWALEVSKY's figure (1871, fig. 35). This larva also has an anterior, unpaired (median) papilla, whereas the other two form a pair.

The Ascidian larva sticks firmly and permanently to the papillae.

The habitat of the Amphioxus larva seems to be chiefly the sea bottom. The question, which I cannot answer, now arises whether the secretion of its *paired papilla* (in a later stage that of the glandular stria on the finfolds) may perhaps serve to attach the larva there for some time. It will then detach itself again by means of the contraction of the lateral muscle to swim away.

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[1]) This reminds us of the postoral, epidermal adhesive organs of the larvae of dipneumonic Lungfishes and of anurous amphibians. The relation of these forms to Amphioxus is so remote, that they remind us rather of an analogy than of a homology.

[2]) In the Ascidian larva the morphologically ventral median line runs from the mouth-opening (which is topographically dorsal) bending round the topographical anterior termination of the larva backwards.

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Rubber Chemistry. — *"Influence of high temperatures on the stress-strain curve of vulcanised rubber."* By A. VAN ROSSEM and H. VAN DER MEYDEN.

(Communicated at the meeting of December 19, 1925).

§ 1. *Introductory. Purpose of the Investigation.*

While the influence of the temperature on the properties of metals and alloys has been studied thoroughly — a recent bibliography [1]) on this subject contains the titles of 216 investigations — the influence of the temperature on the physical properties of rubber has been the subject of only a few limited investigations.

In 1910 P. BREUIL [2]) made a first attempt to study the influence of temperature on the properties of vulcanised rubber, but the dynamometer which he used was inaccurate and his results were far from conclusive.

Later this subject was studied by WORMELEY [3]) and also by DINSMORE [4]) but only in relation to the testing of vulcanised rubber and therefore over a limited range of temperatures (9—35° and 21—35° respectively). Both investigators came to the conclusion that the testing temperature had a strong influence on the results of the tensile tests and suggested, in order to obtain comparative results, tests at constant temperature.

In a recent investigation, LE BLANC and KRÖGER [5]) studied the influence of low temperatures on the stress-strain curve and the sub-permanent set of vulcanised rubber and also carried out some experiments at temperatures higher than the normal. This investigation will be referred to later.

In spite of the limited attention which has been paid to this subject, the study of the physical properties of rubber at elevated temperatures is highly important, from a theoretical, as well as from a practical standpoint, which is obvious from following considerations:

1. Structure theories of vulcanised rubber will be greatly influenced by the knowledge of the properties of this material at high temperatures.

2. For an elucidation of the hot vulcanisation process a thorough

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1) Proceed. Am. Soc. Test. Mat. 24 (II), 128 (1924).

2) Le Caoutchouc et la Gutta Percha 7, 4073 (1910).

3) The Rubber Industry, 1914, p. 246.

4) Cf. Report of the Physical Testing Committee of the Division of Rubber Chemistry of the American Chemical Society. Ind. Eng. Chem. 17, 535 (1925).

5) Kolloid-Zeitschr. 37, 205 (1925).

knowledge of the properties of the rubber at the temperature of vulcanisation will be a necessity. It is often stated that the vulcanised rubber after removal from the hot moulds is quite brittle. This proves that the properties of rubber at the temperature of vulcanisation are different from those of the same rubber at the ordinary temperature.

3. During use, various rubber articles, such as motor car tyres, steam hoses, hot water bottles, etc. are exposed to high temperatures. For the testing of those articles, it is desirable to have an insight into the changes of the properties which take place at high temperatures.

The following part of our study deals only with the influence of high temperatures up to 147° on the stress-strain curve of vulcanised rubber. Elsewhere [1]) the results of this investigation will be published in details. It is our intention to give here a short account of the most important results.

§ 2. *Experimental part.*

For the above mentioned tensile tests with metals at high temperature, the grips of the dynamometer and the test piece are surrounded by an oven, kept at constant high temperature. It is probable, that the complicated technique, which would be necessary to carry out such tests with rubber, has deterred various investigators from this subject.

The technique used in our tensile experiments at high temperatures is a very simple one. The tensile tests were all carried out with rings on the ordinary dynamometer of SCHOPPER. The pulleys, supporting the rings, are heated at the temperature required for the experiment and quickly mounted on the dynamometer, for which procedure 30 seconds are sufficient. Subsequently the ring, which is also heated at the temperature of the experiment, is quickly mounted on the pulleys, which takes about 5 seconds, and the tensile test is immediately started. During the test the ring will cool, but this decrease in temperature will be partly compensated by development of heat during the tensile test. For this reason the temperature of the ring will not be strictly constant during the experiment, but the results described below are so striking that this is no objection in coming to a general conception of the influence of high temperature.

It may be pointed out, that owing to generation of heat during the tensile test, such tests under normal conditions are neither carried out at constant temperature.

The pulleys of the SCHOPPER-dynamometer are heated in an oven and the rubber rings are mounted on a wooden cylinder which is immersed in a mercury bath kept at constant temperature.

Deviations of temperature of the mercury bath were ± 0.5, and it was shown, that the time, necessary for heating the rings to the desired temperature was 1 minute.

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[1]) Journ. Soc. Chem. Ind. 45, 67 T (1926).

Preliminary experiments, which will not be described here, showed, that when studying tensile properties of vulcanised rubber at high temperatures three principal factors must be considered, i.e.:

a. the degree of vulcanisation;

b. the temperature at which the rings are heated and tested;

c. the time, during which the rings are heated.

The principal purpose of a systematic study of the phenomena should therefore be concentrated on the influence of each of these factors.

The first part of these experiments were carried out with rings consisting of a rubber-sulphur mix. From a mix, consisting of 92½ parts of First Latex Sheet (N°. 351 Institute) and 7½ parts of sulphur, a number of slabs were vulcanised in the oilbath at 147° during 60, 90 and 120 minutes time of cure. The vulcanisation coefficient [1]) of these slabs were 2.1, 3.2 and 4.2 respectively. Rings, punched from the slabs were heated at various temperatures, 70°, 100°, 130° and 147°, during progressive time, and tested at the same temperature in the way described above.

In Table 1 are compiled the results of the tensile tests of rings with a vulcanisation coefficient 3.2 and in Figure 1 are reproduced the stress-strain curves of rings, tested at 100° and 147°. The figures are the average of two corresponding tests, except in those cases where brittleness of the rubber occurred and differences in duplo-tests are inevitable.

From Table 1 and Fig. 1 the following can be concluded:

1. When rings are tested at increased temperature the stress-strain curve is shifted towards the elongation axis, in other words, the rubber becomes softer. The higher the temperature of testing, the greater is the shifting of the curve. When testing the rings at high temperatures the elongation at break is increased and especially with rings of low vulcanisation coefficients this phenomenon is striking.

2. Apart from the shifting of the curve a striking phenomenon becomes appearant. When the heating is continued for some time, the tensile and the elongation at break show a sharp decrease, in other words the rings have become brittle.

The time of heating, necessary to cause brittleness of the rings, at a certain vulcanisation coefficient is highly dependent from the temperature. With rings of a vulcanisation coefficient 3.2 brittleness appears at 70°, after heating during 2 $\times$ 24 hours, at 100° after 15 minutes. At 130° and 147° the rings are already brittle after heating only 1 minute.

The same phenomenon was observed with rings of vulcanisation coefficient 2.1 and 4.2 respectively.

In Table 2 the results of those experiments are compiled. From these figures it is obvious, that the time of heating necessary to cause brittleness

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[1]) The quantity of combined sulphur, calculated on 100 parts of rubber.

TABLE 1.

Results of tensile tests with rings heated at 70°, 100°, 130° and 147° during progressive time. (Vulcanisation coefficient 3.2).

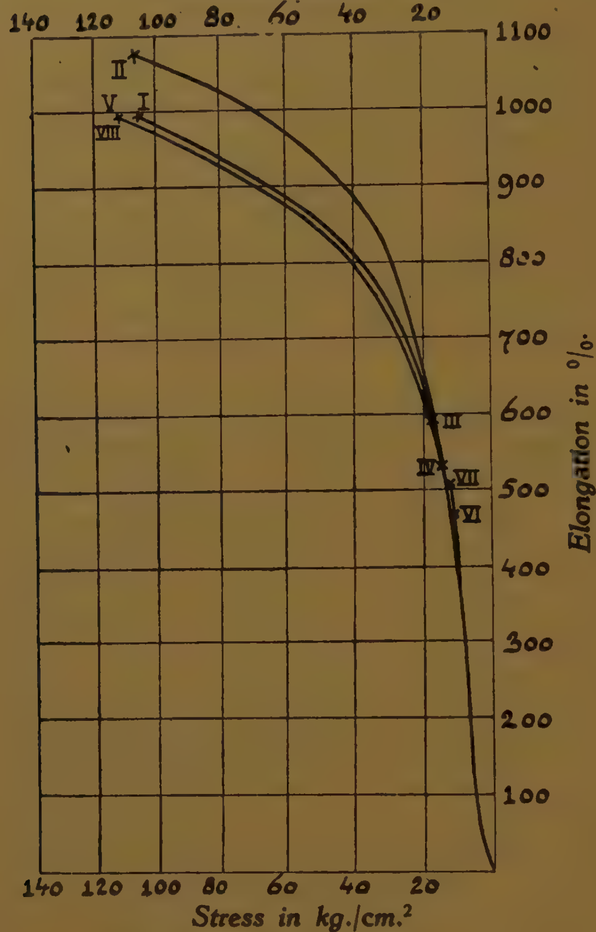
Temperature and time of heating.	Tensile strength in kg./cm².	Elongation at break in %.	Load in kg./cm². for an elongation of 850 %.
Not heated 26° C.	107	990	49
Series at 70° C.			
15 min. at 70° C.	104	1049	37
2 hrs. „ 70 „	109	1040	40
4 „ „ 70 „	113	1040	41
24 „ „ 70 „	112	999	49
2 × 24 hrs at 70° C.	20	568	—
Series at 100° C.			
5 min. at 100° C.	107	1080	34
15 „ „ 100 „	18	595	—
1 hr. „ 100 „	14	532	—
1 „ „ 100 „, subsequently 1 hr. at 25° C.	112	995	51
Series at 130° C.			
1 min. at 130° C.	12	460	—
5 „ „ 130 „	13	500	—
5 „ „ 130 „, subsequently 1 hr. at 25° C.	114	1107	48
Series at 147° C.			
1 min. at 147° C.	12	465	—
5 „ „ 147 „	14	512	—
5 „ „ 147 „, subsequently 1 hr. at 25° C.	115	996	51

decreases quickly with increasing temperature and vulcanisation coefficient.

Rings with vulcanisation coefficient of 4.2 are already brittle after heating 1 min. even at 70°.

3. The brittleness of the rubber is not lasting, in other words, rings which had become brittle through heating, recover their normal tensile

Fig. 1.
Stress-strain curves of rings heated at 100° and 147° C.
(Vulcanisation coefficient 3.2)



I	Blank, not heated (26° C.).				
II	5 min.	at	100° C.		
III	15 „	„	100	„	
IV	1 hr.	„	100	„	
V	1 „	„	100	„	subsequently 1 hr. at 25° C.
VI	1 min.	„	147	„	
VII	5 „	„	147	„	
VIII	5 „	„	147	„	subsequently 1 hr. at 25° C.

properties after cooling. The stress-strain curves of the cooled rings are practically coincident with the original (blank) ones. This is shown in Fig. 1 for rings with a vulcanisation coefficient of 3.2, after heating at 100° and 147°, and subsequent cooling during 1 hour at ordinary temperature.

The same holds true for rings with other vulcanisation coefficients.

Similar experiments were carried out with rings vulcanised from mixes of rubber and sulphur with 10 vol % of various compounding ingredients

TABLE 2.

Relation between occurrence of brittleness, temperature and vulcanisation coefficient.

Temperature of heating.	Time of heating after which brittleness occurs.		
	Vulcanisation coefficient 2,1.	Vulcanisation coefficient 3,2.	Vulcanisation coefficient 4,2.
70° C.	longer than 7×24 hrs.	after 2 × 24 hrs.	after 1 min.
100 „	after 24 hrs.	after 15 min.	„ 1 „
130 „	„ 1 hr.	„ 1 „	„ 1 „
147 „	„ 5 min.	„ 1 „	„ 1 „

e.g.: barytes, zinc oxide and carbon black. With rings from these vulcanised mixes similar phenomena were observed. From the extensive series of experiments with various compounding ingredients the figures obtained with a mix with zinc oxide may be given here as an example.

A mix consisting of 92½ parts of rubber, 7½ parts of sulphur and 57 parts of zinc oxide, Diamond N. (10 % of volume calculated on the rubber) was vulcanised at 147° C. during 50, 90 and 120 min.

The rings, punched from the slabs which showed a vulcanisation coefficient of 1.5, 2.8 and 4.0 respectively were heated during progressive time in a mercury bath at 70°, 100°, 130° and 147°, and tested at the same temperature. The results of the series of tensile tests with rings of a vulcanisation coefficient 4.0 are compiled in Table 3. The stress-strain curves obtained at 100° and 147° are reproduced in Fig. 2.

From Table 3 and Fig. 2 the following can be concluded:

1. At 100° the curve is shifted towards the elongation axis (II). Prolonged heating causes brittleness of the rubber; the endpoint of the stress-strain curve is displaced downwards (III). After cooling, the rings recover their original tensile properties (IV). At 147° the brittleness occurs already after a heating of two minutes (V), the curve returns after cooling to its original position (VI). The changes in physical properties on heating rings with 10 % of volume zinc oxide are essentially the same as those obtained with vulcanised rubber without compounding ingredients. At temperatures of 70° and 100° a difference in the time of heating necessary to cause brittleness, is distinctly visible, while at high temperatures this time is the same, as is shown in Table 4.

Elsewhere the results of the experiments carried out with rubber with various compounding ingredients tested at high temperatures will be published in detail.

TABLE 3.

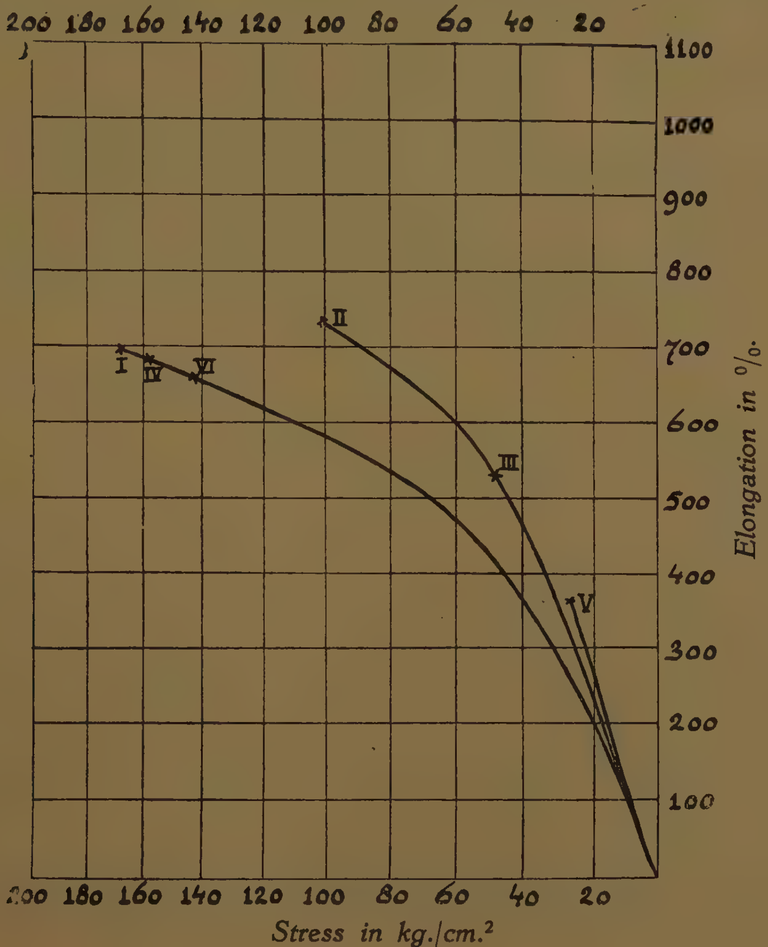
Results of tensile tests with rings with 10 % of volume zincoxide, heated at 70°, 100°, 130° and 147° C. (Vulcanisation coefficient 4.0).

Temperature and time of heating.	Tensile strength in kg./cm².	Elongation at break in %.	Load in kg./cm². for an elongation of 600 %.
Not heated 19°C.	169	699	109
Series at 70° C.			
2 min. at 70° C.	131	740	70
30 „ „ 70 „	133	742	70
24 hrs. „ 70 „	126	700	83
(not continued).			
Series at 100° C.			
2 min. at 100° C.	100	730	59
30 „ „ 100 „	48	530	—
30 „ „ 100 „ subsequently 1 hr. at 20° C.	159	681	113
Series at 130° C.			
2 min. at 130° C.	44	560	—
2 „ „ 130 „ subsequently 1 hr. at 20° C.	162	687	109
Series at 147° C.			
2 min. at 147° C.	26	355	—
2 „ „ 147 „ subsequently 1 hr. at 19° C.	143	659	109

§ 3. *Concluding remarks.*

In the first place we wish to check our results with those obtained by LE BLANC and KRÖGER (loc. cit.). As mentioned before these investigators have studied especially the influence of low temperature on the stress-strain curve of vulcanised rubber, but they have carried out also some experiments at higher temperature (till 80°). They used a special testing apparatus which was connected with the SCHOPPER-dynamometer. The rings were heated in alcohol. At elevated temperatures this method seems objectionable. They carried out tensile tests with a rubber-sulphur mix,

Fig. 2.
Stress-strain curves of rings, containing 10 % of vol. zincoxide, tested at 100° and 147° C.
(Vulcanisation coefficient 4.0).



I	Blank, not heated (19° C.).				
II	2 min.	at	100° C.		
III	30 „	„	100 „		
IV	30 „	„	100 „	subsequently 1 hr. at 20° C.
V	2 „	„	147 „		
VI	2 „	„	147 „	subsequently 1 hr. at 19° C.

with progressive time of cure, without mentioning vulcanisation coefficients. Rings with low degree of vulcanisation were heated to 55° and the figures show clearly a shifting of the tensile curve towards the elongation axis. Rings with higher degrees of vulcanisation were always found to be brittle. They conclude from their results :

„Bemerkenswert ist, dasz bei Temperaturen über 30° wirklich gute Eigenschaften überhaupt nicht erhalten werden können. Am günstigsten liegen die Verhältnisse in dieser Beziehung bei den ausvulkanisierten

Produkten. Jenseits von 60° ergeben sich nur wenige Kilo Belastungsfähigkeit, offenbar infolge der Zunahme des Wärmeinhalts über einen kritischen Betrag, wodurch einmal bei längerem Erwärmen die bekannte Desaggregation merkbar einsetzt und anderseits die Kräfte die dem Zerreiszen entgegenwirken, geschwächt werden."

TABLE 4.

Brittleness of rings with and without 10 % of vol. zincoxide.

Temperature of heating.	Time of heating, after which brittleness occurs.	
	Rings without zincoxide Vulcanisation coefficient 4.2.	Rings with 10% of vol. zincoxide Vulcanisation coefficient 4.0.
70° C.	after 1 min.	after longer than 24 hrs.
100 „	„ 1 „	after 30 min.
130 „	„ 1 „	„ 2 „
147 „	„ 1 „	„ 2 „

This conclusion is in contradiction with our results. With a low coefficient of vulcanisation excellent tensile properties could be recorded even at 100° and at 130°, when the period of heating was not too long.

Le Blanc and Kröger have left out of consideration the time of heating, which is of paramount importance. For this reason they did not get a complete survey of the influence of high temperatures on the stress-strain curve.

Finally we wish to make a few remarks in relation to the cause of the described phenomena. It is not our intention now to put forward an explanatory theory of the phenomena just described, but only to point out a few directions in which the experimental study will be continued. The important observation of brittleness at high temperature gives us cause to the following points.

1. It is well known that overvulcanisation causes brittleness at ordinary temperature. In this respect the brittleness at high temperature might be attributed to overvulcanisation due to prolonged heating. This is not the case as is obvious from determinations of vulcanisation coefficients before and after heating in the mercury bath which proved to be the same. Moreover it was a priori improbable that overvulcanisation should be caused by heating during one or two minutes at 147°.

2. When vulcanised rubber is heated in air at high temperature, oxidation takes place, which causes a decrease in physical properties, determined at ordinary temperature (dry heat or ageing test). In our experiments the air was not in contact with the rubber, because the rings were heated in a mercury bath, and therefore oxidation is improbable.

3. Brittleness at high temperature must be ascribed in our opinion to another cause than brittleness at room temperature from overvulcanisation.

Brittleness at high temperature is likely to stand in close relation with an increase of plasticity at high temperature [1]).

Two methods of further investigation propose themself to verify the correctness of these suppositions :

a. A closer study of the sub-permanent set at high temperature, because this property stands in relation with the plasticity.

b. Direct measurement of the plasticity of rubber at high temperatures.

Finally attention may be drawn to the possibility that a closer study of the conduct of vulcanised rubber at high temperature leads to a new method of carrying out ageing experiments.

The investigation of the properties of vulcanised rubber at high temperature is continued in the directions here described.

Netherland Government Rubber Institute.

Delft, December 1925.

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[1]) It is sometimes pointed out wrongly that a high degree of plasticity is always accompanied by a high elongation. This is not the case as is obvious from a plastic material as putty.

Physics. — "*The variation of the dielectric constant of liquid oxygen with temperature.*" By WACLAW WERNER and W. H. KEESOM. (Communication N⁰. 178*c* from the physical laboratory at Leiden.)

(Communicated at the meeting of January 30, 1926).

§ 1. *Introduction.* The dielectric constant of liquid oxygen has already been investigated by FLEMING and DEWAR [1]), by HASENÖHRL [2]) and by BREIT and KAMERLINGH ONNES [3]). The latter also investigated its variation with temperature. The results differ from each other by 2 %, and this is to be ascribed to the fact that electrostatic methods are less accurate than high frequency methods, such as used by BREIT and KAMERLINGH ONNES. As however the capacity of their connecting wires was not known accurately the absolute values of their provisional results are too small [4]), and we thought it desirable to repeat the measurements with greater accuracy.

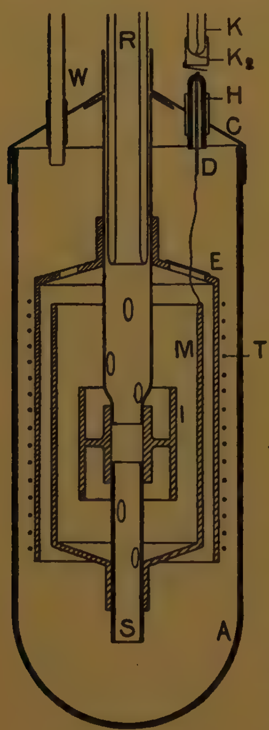

Fig. 1.

§ 2. *Method.* We have made use of the method and the apparatus, which we used for the measurement of the D. C. of liquid and solid hydrogen. From the boiling-point to $T = 68^\circ.5$ we also used the same condenser with a capacity of about 60 cm. (the condenser A).

At lower temperatures the liquid cryostat had to be replaced by a hydrogen vapour cryostat. For this a new condenser (condenser B) was constructed according to our ideas by G. J. FLIM, to whom we render our best thanks. This condenser has 3 plates E, M and I. E and I were soldered to a copper tube, into which the glass vacuum tube R reaches. The copper tube was narrowed at the lower end and provided with holes. To I was soldered a single glass tube S provided with holes, to which the plate M was fixed. E and I, and also the metal cap H were earthed. By means of

[1]) J. A. FLEMING and J. DEWAR. Proc. Roy. Soc. **60**, 358, 1890. They found at the boiling-point $\varepsilon_B = 1.493$.

[2]) F. HASENÖHRL. These Proc. **2**, 211, 1899, Leiden Comm. N⁰. 52. $\varepsilon_B = 1.465$.

[3]) G. BREIT and H. KAMERLINGH ONNES. These Proc. **27**, 617, 1924; Leiden Comm. N⁰. 171*a*, $\varepsilon_B = 1.463$.

[4]) Compare our communication in these Proc. **29**, 34, 1926; Leiden Comm. N⁰. 178*a*.

the connecting wire D and the movable contact K, which was provided with an elastic silver plate K_2, M could be switched in parallel to the measuring condenser or switched off. The plates M and I were also provided with holes. These holes, as well as the vacuum tube R served for making the entry of liquid during contraction possible, and in order to prevent as much as possible the formation of vacuols on solidification for the measurements in the solid state. The capacity of the condenser was about 21 cm.

In the measurements with condenser A the temperature in the condenser vessel as well as that in the cryostat bath, was calculated from the pressure of the saturated vapour. The temperatures were then calculated from the formula of CATH-VERSCHAFFELT [1]).

For condenser B a platinum wire of 0.05 mm. diameter and ca. 52 Ω resistance served as a thermometer. This platinum wire was wounded round the outmost plate of the condenser and insulated from it by means of mica. This thermometer was calibrated with the aid of the platinum thermometer Pt_{24} in the hydrogen vapour cryostat.

§ 3. *The course of the measurements.* The measurements with the condenser A were made in the same way as our measurements for hydrogen. As the exchange of the temperature took place slowly, a temperature decrease was often observed during the measurement; in such cases the results of the separate measurements were reduced to a mean temperature and after that the average was taken.

For the measurement with condenser B this condenser was evacuated, cooled in the vapour cryostat to the right temperature and its capacity measured. Then the condenser was filled with newly condensed oxygen, and brought to the right temperature. The capacity was measured again. The oxygen was taken from a high pressure cylinder. From analysis the contents of this cylinder appeared to contain 2.4 % admixtures, mainly nitrogen.

As the temperature exchange for this condenser was very slow, the measurements were made during the cooling. The rapidity of cooling was generally 0.01 to 0.04 degree per minute. The case, in which it was greater, is indicated in table II. The temperature was read off each 3 or 5 minutes. For a series of 7 to 11 adjustments of the measuring condenser, alternately with or without the experimental condenser, the mean values of capacity and temperature were calculated. These values are given in Table II, the necessary correction (§ 4) having been applied. Although this manner of working with a slowly decreasing temperature diminished the accuracy of the measurements somewhat, it, however, made it possible to read more points and so to follow better the course of the D. C. with temperature.

1) P. G. CATH. These Proc. **21**, 656, 1918, Leiden Comm. N⁰. 152*d*.

§ 4. *Calculation and corrections.* The value, found for the capacity, was corrected for the calibration of the scale. The D. C. was calculated as the ratio between the capacities of the condenser filled and empty. This value had still to be corrected for the capacity of the connecting wires. For condenser *A* the correction was made in the same way as for the measurements with hydrogen, and amounted to 0.0018 to 0.0019.

For condenser *B* the capacity of the wire *D* was important. This capacity was due chiefly to that part of the wire that was surrounded by the metal tube *H*. This capacity was measured directly and corresponded to 0.96 scale-divisions. This correction was applied to measurement N⁰. 12 (boiling-point), which was made in the liquid cryostat. In this measurement the level of the liquid was below the tube *H*. With all other measurements the liquid was high in the tube *R*, so that the tube *H* was also filled with the liquid to be investigated. For each temperature the capacities of the condenser consisting of tube *H*, glass tube and wire in empty and filled state were calculated from the measurements of this condenser and the capacity was subtracted from the measured capacities. The dielectric constants calculated so, differ from the values not corrected by 0.0002 to 0.0004.

§ 5. *Accuracy.* The accuracy of the measurements with condenser *A* was of the same order of magnitude as that of the measurements with hydrogen. It was for a capacity measurement 0.15 per mil, and hence was for a determination of the D. C. 0.3 per mil. The mean error of the value of the D. C. at the boiling-point, calculated from three measurements, was 0.15 per mil. The measurements with condenser *B* were less accurate, as its capacity was smaller, and as at each temperature only one measurement could be made [1]). The mean error of a capacity measurement was 1 per mil, hence the determination of the D. C. can be considered as being accurate to 2 per mil.

For the measurements with condenser *A*, the temperature was derived from the pressure of the cryostat bath. The accuracy of 0.5 mm. of the pressure measurement corresponds to an accuracy of the temperature measurement of ca. 0.01°. We are, however, especially for the measurements at the boiling-point, not perfectly certain of the purity of the cryostat liquid. Meanwhile the temperature measurement can be considered as being accurate to 0.1°.

For condenser *B* the temperature could be measured to 0.01° by means of the platinum thermometer. If we take however into account the change of the temperature during the measurement, and the possible errors in the calibration curve, we can consider the accuracy of the temperature determination for this condenser as also being 0.1° [2]).

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[1]) The measurements Nos. 11 and 12 both consist of 3 separate measurements; their accuracy is comparable with the measurements with condenser *A*.

[2]) For the influence of the oxygen being not perfectly pure see p. 309 note 3.

§ 6. *Results.* Table I contains the results obtained with condenser *A*. Series I was performed with the paper scale, series II with the metal scale [1]).

TABLE I.
Condenser A.

1	2	3	4	5	6	7	8	9	10	11
Series	No.	Date	Pressure		Temperature		Capacity		Dielectr. const.	
			p_i	p_e	T_i	T_e	C	C_0		corrected
I	1	28.III '25	81.9	76.3	90.87	90.70	137.94		1.4807	1.4825
	2	"	47.7	43.6	85.89	85.12	138.94		1.4914	1.4932
	3	"	23.6	21.5	80.28	79.57	139.98		1.5026	1.5045
	4	"						93.16		
II	5	19.VI						84.87		
	6	"	76.8	76.2	90.23	90.15	125.75		1.4817	1.4833
	7	22.VI						84.81		
	8	"	15.9	14.55	77.45	76.85	128.25		1.5128	1.5145
	9	"	9.2	8.0	73.90	73.04	128.85		1.5199	1.5216
	10	"	3.55	3.25	68.47	68.02	129.95		1.5328	1.5346

p_i and T_i relate to the condenser vessel, p_e and T_e to the cryostat bath.

Table II contains the results of the measurements with the condenser *B*.

Table III contains the results of the measurements N⁰. 1, 6 and 12, made under atmospheric pressure. $\Delta\varepsilon$ represents the correction necessary for the reduction of the measurements to the boiling-point of oxygen, $T = 90°.14$ K [2]). So the mean value

$$\varepsilon_B = 1.4837$$

gives the value of the dielectric constant of liquid oxygen at the boiling-point [3]).

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1) Comp. our paper about hydrogen, l.c.

2) P. G. CATH, l.c.

3) From measurements by Dr. L. EBERT and one of us, shortly to be published, of the D. C. of liquid nitrogen, we can derive that the amount of nitrogen, that might have been present in the liquid (comp. § 3), would make the value of the D. C. somewhat too small, but the influence of it is less than 1.3 per mil. Some control measurements with pure oxygen confirm our results. These control measurements were made by Dr. EBERT, to whom we render our best thanks.

TABLE II.

Series III. Condenser B.

No.	Date	Temperature	Capacity		Dielectr. const.		Remarks
		T	C_0	C		corr.	
11	7 VII '25		32.73				
12		90.38		48.09	1.469_2	1.483_0	in the liquid -cryostat
13	18 IX		33.05				
14		61.5		51.20	1.549_1	1.549_3	
15		60.8		.37	$.554_3$	$.554_5$	
16		58.1		.33	$.559_2$	$.559_4$	
17	25 IX		32.33				
18		55.4		50.79	1.570_9	1.571_2	
19		55.0		.77	$.570_3$	$.570_6$	
20		54.4		51.40	$.589_8$	$.590_2$	
21		54.33		.53	$.593_9$	$.594_3$	partly under-cooled
22		54.34		.29	$.586_4$	$.586_8$	solid
23		„		.27	$.585_8$	$.586_2$	
24		54.20		.58	$.595_4$	$.595_8$	rapid cooling
25		53.75		.98	1.607_8	1.608_3	
26		53.6		52.14	$.612_4$	$.612_9$	
27		52.8		.10	$.611_5$	$.612_0$	
28		51.6		.00	$.608_4$	$.608_9$	
29		51.3		.02	$.609_0$	$.609_5$	

TABLE III

N^0.	T	ε	$10^4 . \Delta\ \varepsilon$	ε_{red}	Average
1	90.87	1.4825	16	1.4841	$\varepsilon_B = 1.4837$
6	90.23	1.4833	2	35	$\pm$ 0.0200
12	90.38	1.4830	5	35	

Though the measurements were made with two different condensers, the agreement of the results is satisfactory. The value obtained, is almost

that of DEWAR[1] (1.493); the difference is less than 1 %, and this is what DEWAR gives as the limit of the accuracy of his measurements.

From the values, which LIVEING and DEWAR[2] give for the dispersion of light in liquid oxygen, DEWAR[3] calculated for the value of the refractive index for infinitely long waves $n_\infty = 1.2181$. From this $n_\infty^2 = 1.4838$[4] follows, which agrees very well with our results for the dielectric constant, indicating that oxygen molecules do not bear electric doublets.

Table IV contains the values of the D. C. from the 3 observation series,

TABLE IV.

N⁰.	T	ε	ρ	$P=\frac{\varepsilon-1}{\varepsilon+2}\frac{1}{\rho}$	PT
1,6,12	90.14	1.4837	1.1466	0.1211	10.916
2	85.89	932	.1678	09	10.384
3	80.28	1.5045	.1948	05	9.673
8	77.45	145	.2080	12	9.386
9	73.90	216	.2244	10	8.940
10	68.47	346	.2487	11	8.295
14	61.5	49_3	.2797	09	7.437
15	60.8	54_5	.2829	16	7.393
16	58.1	59_4	.2945	12	7.044
18	55.4	71_2	.3060	25	6.785
19	55.0	70_6	.3078	22	6.721
20	54.4	90_2	.3102	55	6.826
21	54.33	1.594_3	.3105	62	6.853

tabulated after the temperatures, and contains also the values of the function of CLAUSIUS—MOSOTTI $P=\frac{\varepsilon-1}{\varepsilon+2}\frac{1}{\varrho}$ and of the product PT. From the boiling-point to 58° K. ε has a rectilinear course, see fig. 2. At 55° a small increase begins, which becomes very obvious at 54°.4 K. The results, obtained with the two condensers fit very well onto the same straight line.

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1) J. DEWAR l.c. The absolute values of BREIT and KAMERLINGH ONNES are too small owing to the reason mentioned in § 1; when reduced to the right values, they show the same dependance on the temperature; only the accidental errors are greater.

2) LIVEING and DEWAR. Phil. Mag. (5) 40, 269, 1895.

3) J. DEWAR, l.c.

4) For vibrations with the frequency of the lightwaves, we can take the magnetic permeability as being 1.

Accordingly P has an almost constant value, namely $P = 0.1211$ [1]; the largest deviations are 0.5 %. This again according to DEBIJE's theory [2] points to the fact that liquid oxygen is to be considered as a liquid free from electric doublets.

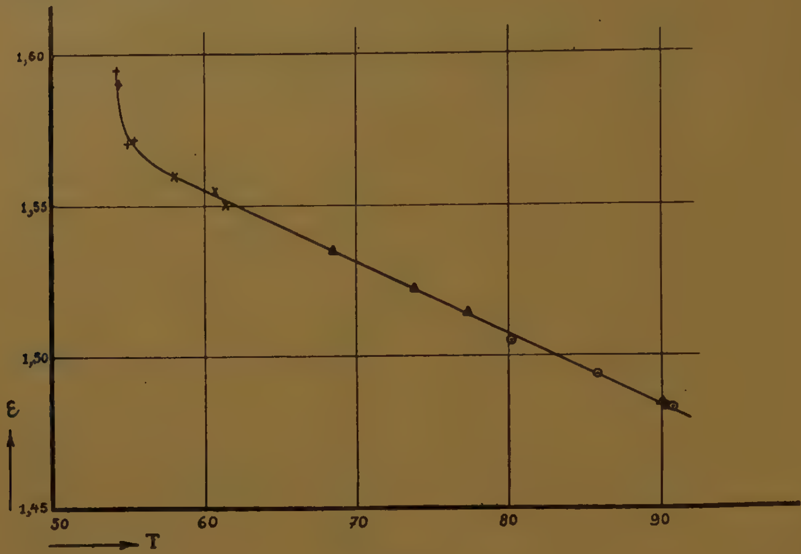

Fig. 2.

This appears still clearer on considering the products PT. Prof. M. WOLFKE was so kind as to calculate from our measurements Nos. 1—19 the constants of DEBIJE's formula:

$$PT = a + bT$$

by the method of least squares.

He obtained

$$a = -0.01136, \qquad b = 0.1212.$$

The negative value of a as well as its small value indicate, that this result for a is caused by accidental errors, so that a can be considered as being 0, from which, as a is proportional to μ^2, it follows again that the molecular electric doublet moment $\mu = 0$.

The factor b agrees very well with the optical value of PT calculated from the data of LIVEING and DEWAR:

$$PT = \frac{n^2-1}{n^2+2} \cdot \frac{T}{\varrho} = 0.1211.$$

The measurements of 25 IX (table II) extend to below the melting-point,

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[1]) From the measurements of FRITS (Phys. Rev. 23, 345, 1924) it follows that for gazeous oxygen $P = 0.1183$; for oxygen with 2.4% nitrogen $P = 0.1190$.

[2]) We must bear in mind, however. that the application of DEBIJE's theory to liquids is not quite safe, as in it the mutual actions between the molecules are not taken into account, cf. SÄNGER, Physik. Zs. 27, 165, 1926. *(Note added in the translation).*

and thus also include observations on the solid state. These as well as further experiments, made by us, leave several points unexplained. The discussion of these results must be delayed till a later publication.

Summary.

1. The D. C. of liquid oxygen was measured from the boiling-point to the melting-point.

2. For the D. C. of liquid oxygen at the boiling-point $T = 90°.14$ K. was found:

$$\varepsilon_B = 1.4837.$$

3. The function of CLAUSIUS—MOSOTTI $P = \frac{\varepsilon - 1}{\varepsilon - 2} \frac{1}{\varrho}$ is constant to 0.5% from the boiling-point to $T = 58°$. At further cooling P increases from 0.121 to 0.126.

4. From the calculation of the coefficients in the formula of DEBIJE $PT = a + bT$ follows, that in liquid oxygen the molecules have no own doublet moments.

Biochemistry. — *"On bimolecular layers of lipoids on the chromocytes of the blood."* By E. GORTER, M. D., and F. GRENDEL. (From the Laboratory of Pediatrics of the University of Leyden, Leyden, Holland.) (Communicated by Prof. P. EHRENFEST.)

(Communicated at the meeting of February 27, 1926).

In a previous communication [1]) we have demonstrated that the quantity of lipoids contained in chromocytes of different animals is exactly sufficient to cover the surface of these chromocytes in a layer that is two molecules thick. In this paper we intend to discuss some technical details.

Before entering into this discussion we give some more results obtained with the technique described in our previous paper, making use of acetone as extractionfluid in large quantities.

TABLE I.
Acetone extraction, large quantities.

	Animal	Amount of blood used for the analysis.	No. of chromocytes per c.mm.	Surface of one chromocyte	Total surface of the chromocytes (*a*)	Surface occupied by all the lipoids of the chromocytes (*b*)	Factor *b*:*a*
		gm.		sq. μ	sq. m.	sq. m.	
20	Guinea-Pig B	10	5.630.000	100.8	5.7	11.6	2
21	„ C	1	5.800.000	92.5	0.53	1.02	2
22	Rabbit C	0.5	6.100.000	90	0.28	0.6	2.1
23	„ C	0.5	6.100.000	90	0.28	0.58	2.1
24	„ D	1	5.600.000	92.4	0.51	0.92	1.8
25	Goat 2	0.5	14.000.000	23	0.16	0.35	2.2
26	„ 2	5	14.000.000	23	1.6	3	1.9
27	„ 2	5	14.000.000	23	1.6	3.2	2.0
28	Man HG	2.5	5.200.000	123	1.6	3.0	1.9
29	„ JR	1	2.060.000	90	0.18	0.35	1.9
30	Dog B	5	9.700.000	101	4.9	9.8	2
31	„ C	1	4.340.000	124.8	0.54	1.08	2
32	„ C	1	4.340.000	124.8	0.54	1.08	2

[1]) *Journal of exper. medicine*, April 1, 1925, Vol. XLI, No. 4, 439—443.

We now want to emphasize the importance of using large quantities of acetone. When less than 3 × 100 cc. acetone per 1 cc. of blood are used, the extraction may be incomplete, so much so that in this case a second extraction may give an important part of the unextracted lipoids.

TABLE II.
Influence of quantity of acetone used.

	Animal	Amount of blood used for the analysis	Quantity of acetone used for the analysis	Total surface of the chromocytes	Surface occupied by the lipoids as determined		Bimolecular layer of lipoid. theoretical
		c.c.	c.c.	sq.m.	sq.m.		sq.m.
33	Man H.G.	1	2 × 30	0.64	0.67		1.28
34	„ „	1	3 × 30	0.64	0.84		1.28
35	„ „	2.5	3 × 125	1.6	2.7		3.2
36	„ „	2.5	3 × 150	1.6	3		3.2
37	Sheep 2	10	3 × 150	4.2	6.8		8.4
38	„ 2	10	3 × 150	4.2	15.1	8.1	8.4
				Second extraction	3		
39	Dog B	10	3 × 150	9.8	15	16.2	19.6
				Second extraction with alcohol	1.2		
40	„ „	10	3 × 150	9.8	14.4	18.4	19.6
				Second extraction with acetone	4		

Although in many of our experiments with acetone subsequent extraction with different solvents of lipoids had never yielded more than traces of spreading substances we have controlled our results by a different method.

We therefore made use of BLOOR's method of extracting lipoids.

In a glassbeaker of 100 cc. we filled 30—40 cc. of the alcohol-ether mixture (3 : 1) and under continuous shaking we added the washed chromocytes from 1 cc. of blood.

The mixture was then heated till boiling tempertature, cooled under the tap and made up to 50 cc. with alcohol-ether mixture and then filtered. The filtrate was evaporated to dryness on a waterbath and bumping of the fluid prevented by adding some platinum tetraeders. The residue was finally taken up in benzene and filtered into a measuring-flask of 10 cc. 0.1 cc. was pipetted on to the watersurface of the Langmuir-Adam apparatus.

The results obtained by this method were concordant with those already communicated, as is shown in table III.

TABLE III.

Results obtained by BLOOR's method.

	Animal	Amount of blood used for the analysis	No. of chromocytes per c.mm.	Surface of one chromocyte	Total surface of the chromocytes (*a*)	Surface occupied by all the lipoids of the chromocytes (*b*)	Factor *b* : *a*
		c.c.		sq. μ	sq. m.	sq. m.	
41	Man	1	5.200.000	123	0.64	1.29	2
42	„	1	5.200.000	123	0.64	1.26	2
43	„	2.5	5.200.000	123	1.6	3.1	2
44	Rabbit E	1	5.950.000	92.5	0.55	1.1	2
45	Goat 3	1	27.220.000	21.1	0.57	1.2	2.1
46	„ 3	1	27.220.000	21.1	0.57	1.15	2
47	„ 3	1	27.220.000	21.1	0.57	1.17	2

When, as we have tried to do, hoping to extract more lipoid matter, the extraction is made three times and the blood is heated for some time after the boiling temperature has been attained, the results are bad. It is highly

TABLE IV.

Results in using large quantities and prolonged heating.

	Animal	Amount of blood used for the analysis	No. of chromocytes per c.mm.	Surface of one chromocyte	Total surface of the chromocytes (*a*)	Surface occupied by all the lipoids of the chromocytes (*b*)	Factor *b* : *a*
		c.c.		sq. μ	sq. m.	sq. m.	
48	Sheep	10	11.500.000	36.5	4.2	9.9	2.3
49	„	10	11.500.000	36.5	4.2	10.4	2.5
50	Dog B	10	9.700.000	101	9.8	22.4	2.3
51	„ B	10	9.700.000	101	9.8	23.7	2.4
52	Rabbit C	0.5	6.100.000	90	0.28	0.7	2.5
53	„ C	0.5	6.100.000	90	0.28	0.65	2.3
54	„ F	5	5.550.000	87	2.4	5.7	2.4

probable that these results are due to other substances than lipoids because the extract is deep-brown.

Now blood-pigment and its derivatives spread on a watersurface. (Hemin in ether e.g. $\pm 70 \times 10^{-16}$ sq. cm.)

In our last experiments we modified the technique of determining the size of the bloodcells. Instead of drawing the cells on millimeterpaper we made use of PYPER's method [1]. In controlling determinations the numbers obtained by this method agreed fairly well with those from direct measurements.

It has struck us that direct measurement of the alcohol-ether mixture gave very variable results, mostly far too small. We were able to show that also by solving pure fatty acids in alcohol the results were often very bad, and in several instances one obtains half the right value. These results were partly due to the technical difficulty of bringing the alcohol exactly on the surface of the water in the tray, partly to the character of the substance, in so far as oleic acid and triolein were more apt to give good values than solid substances like palmitic acid or tripalmitin. Possibly the explanation of the half values lay in the association of the molecules of these fatty acids in alcohol [2].

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1) BERGANSIUS, *Arch. ges. Physiol.*, 1921. CXCII, 118.

2) W. ROSS INNES, Journ. Chem. Soc. **113**, 1918, 410 found for hexadecylalcohol in alcohol 1.5 times the normal molecular weight.

Biochemistry. — *"On the spreading of the different lipoids from chromocytes of different animals."* By E. GORTER, M. D., and F. GRENDEL. (From the Laboratory of Pediatrics of the University of Leyden, Leyden, Holland). (Communicated by Prof. P. EHRENFEST.)

(Communicated at the meeting of February 27, 1926).

In the paper of BEUMER and BÜRGER [1]) we were able to find exact indications on the different lipoids found in the chromocytes of the sheep. They have obtained from 1 Litre of blood

0.5 gm. sphingomyelin
0.5 gm. kephalin etc.
0.5 gm. cholesterol.

Through the kindness of Dr. LEVENE from the Rockefeller Institute we were enabled to determine the spreading value of these substances. He put at our disposal a pure specimen of sphingomyelin and a specimen of kephalin containing 25 % of lecithin.

In order to enable the reader to compare the values, we give not only the spreading per 1 mg. of the material, but also the spreading per molecule.

	Spreading per molecule	Spreading per 1 mg.
	sq. cm.	sq. cm.
Kephalin (with 25 % lecithin)	116×10^{-16} [2])	0.84×10^4
Sphingomyelin	46×10^{-16}	0.35×10^4
Cholesterol	40×10^{-16}	0.62×10^4
Cholesterol palmitate	20×10^{-16}	0.19×10^4

Assuming that the chromocytes do not contain cholesterol in esterform we were able to calculate the total spreading of the lipoids extracted by BEUMER and BURGER from 1 cc. blood of a sheep.

Kephalin etc.	0.42×10^4	sq. cm.
Cholesterol	0.31×10^4	,,
Sphingomyelin	0.75×10^4	,,

[1]) BEUMER and BÜRGER, Biochem. Z., 1913, LVI, 446.

[2]) LEATHES found 114×10^{-16} per molecule of lecithin.

We get the impression that the surface is covered by kephalin and a second layer is formed by cholesterol and sphingomyelin combined. Although it is impossible to know the exact numbers of the chromocytes and their size in the blood, that was extracted by BEUMER and BüRGER, we can solidify this hypothesis by calculating the surface of one cc. blood from the mean values given by KLIENEBERGER [1]) (11.800.000 per sq. mm. and 4.3 μ as diameter) and one gets:

$$0.44 \times 10^4 \text{ sq. cm.}$$

It seems superfluous to make these calculations from other determinations in different publications, in which the amount of blood used for the extractions is unknown. Therefore we undertook to make ourselves these determinations in some experiments. The most simple appeared to be the exact determination of the cholesterol-content of an extract of blood, that had already served to the purpose of determining the total spreading value.

We made use of the Liebermanntest. The benzene solution of all the lipoids of the red blood cells or a Bloor-extract of the chromocytes of the same blood was evaporated on the waterbath just to dryness, and the warm residue taken up in chloroform. This chloroform-solution served directly to the colorimetric determination of the cholesterol.

All this experiments show conclusively that $^2/_5$ of the surface occupied by all the lipoids of the blood cells, is occupied by cholesterol.

It was impossible to work out a simple method for determining the other lipoid-constituents. Because sphingomyelin as well as kephalin (and lecithin)

	Animal	Amount of blood	Total surface of the chromocytes (*a*)	Total surface of all the lipoids of the chromocytes (*b*)	Surface occupied by cholesterol of the chromocytes (*c*)	Factor c:b
		cc.	sq.m.	sq.m.	sq.m.	
55	Cavia C	1	0.53	1.02	0.4	0.39
56	„ C	5	2.65	(5.1)	2	0.39
57	„ C	3	1.59	(3.06)	1.2	0.39
58	Rabbit D	5	2.55	4.60[2])	2.1	0.45
59	Sheep 2	10	4.19	8.07	3.4	0.42
60	Dog B	10	9.8	18.4	7.4	0.40
61	Goat 2	5	1.6	3.2	1.3	0.40

[1]) KLIENEBERGER und CARL, Die Blut-Morphologie der Laboratoriums-Tiere, Leipzig, 1912.
[2]) This number probably too small.

both contain phosphorus and the spreadingvalue of these substances differs considerably, the determination of the total lipoid phosphorus would serve no good purpose. Some determinations however gave the result that in the assumption that half of the phosphorus was derived from sphingomyelin and the other half from kephalin, the total spreading was exactly explained but other experiments gave inconstant results.

We therefore only give the numbers of the cholesterol.

We want to add a few words on the different character of kephalin and lecithin on the one side and cholesterol and sphingomyelin on the other side. The first named substances are in the expanded condition [1]), the last mentioned in the condensed form at 37° C. It seems possible, that these properties counterbalance each other in a certain sense on the surface of the chromocytes.

We wish to thank Dr. LEVENE for kindly sending us a sample of kephalin and of sphingomyelin.

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1) ADAM, Proc. Roy. Soc. London, Series (A), 1922. CI, 516.